For Reference

NOT TO BE TAKEN FROM THIS ROOM

Ex libris
universitatis
albertaensis

QUAECUMQUE VERA

THE UNIVERSITY OF ALBERTA

A GPSS COST-BENEFIT SIMULATION OF FORAGE HANDLING

by

© KENNETH WILLIAM LIEVERS

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF AGRICULTURAL ENGINEERING

EDMONTON, ALBERTA

FALL, 1971

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "A GPSS Cost-Benefit Simulation of Forage Handling" submitted by Kenneth William Lievers in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The optimum forage handling system for a farm firm is not necessarily the one minimizing machinery costs. Consideration must be given to the interdependence of all systems on the farm in order to select a forage harvesting and handling system that permits the farm operator to maximize his net returns. The objectives of this thesis were to compile existing data pertaining to forage handling, to computer simulate some of the present alternative systems applicable to forage harvesting and handling, to test the suitability of the General Purpose Simulation System/360 (GPSS) in generating and costing such systems, and to propose other mathematical methods of evaluating alternative systems.

It was premised that legume-forage crops in the Edmonton area are primarily grown and harvested for their protein value. The objective function of this cost-benefit analysis was therefore defined as minimum cost per ton of digestible protein fed. The method used to generate and cost alternative systems involved both network analysis and simulated sampling techniques. The GPSS programs randomly selected alternative routes through the network, simulating several years of harvesting weather for each, and calculating fixed, variable and penalty costs incurred as the forage moved from field to exit from storage. Penalty costs associated with harvesting delays and weather damage were assessed using weather probability functions, a simulated sampling of harvest weather, and a cost calculation of lost feed value. Some program parameters were given a uniform probability distribution of values. Annual fixed, variable and penalty costs were calculated for

each stage of the system before another pass was made through the network.

The analysis of these simulated systems showed that, for many systems, penalty costs per harvested acre comprised a significant proportion of total annual costs. Thus, a knowledge of how nutritional values and drying rates of mechanically treated forage relate to weather parameters is important. The lack of this information constitutes a serious data gap.

After the simulated systems were ranked in accord with the predetermined objective function, the cost sensitivity of the systems became apparent. In the section of the network successfully programmed, one of four different end products was selected for each route - high moisture silage, wilted silage, haylage and dehydrated forage - the general advisability of each ranked in the same order. Within the reliability of data and sample sizes used, no one system was always preferable to the one next in rank. Cost distributions for systems overlapped to a considerable extent.

The suitability of the GPSS approach is questionable. The trade-off existing between computer time and storage requirements will influence the selection of an alternate method. Any comparative evaluation of forage harvesting and handling systems requires simulated sampling at some point in the analysis, unless stochastic variables are approximated with constant values. Three other possible mathematical methods that could be used are (1) simulated sampling and separable programming, (2) Shortest Path Network Analysis (SPNA) and Monte Carlo techniques, and (3) dynamic programming and simulated sampling. This latter possibility eliminates the necessity of evaluating every possibility in the network.

ACKNOWLEDGEMENT

The guidance and assistance provided by Dr. F.V. MacHardy is gratefully appreciated. The competent supervision given and the helpful suggestions made enabled completion of this thesis as presented. Suggestions concerning manuscript organization and presentation lightened the workload of these final tasks and made them more meaningful.

A sincere thank you goes to Mr. D.G. Russell who so often provided programming suggestions, and spent a lot of time submitting and collecting programs. Also, the assistance given by many of the staff of the Computing Science Department is acknowledged.

The information so kindly offered by the local machinery salesmen when pertinent and necessary data were requested, made the analysis easier and far more relevant. Any mention of trade names in the text implies neither criticism nor endorsement by the author, but was deemed necessary for the sake of clarity.

The hours spent by the Misses K. Lievers, S. Dickson and B. Howitt in typing preliminary drafts of the manuscript, and the extensive hours spent by Miss E. Symons in typing the final manuscript are gratefully appreciated. Typing this thesis with its many graphs and often voluminous tables meant a lot of painstaking effort. Their help, as well as the help of many not mentioned, is acknowledged.

TABLE OF CONTENTS

ABSTRACT

ACKNOWLEDGEMENT

APPENDICES

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION AND OBJECTIVES

Optimum forage harvesting and handling systems cannot be arrived at without consideration of other farm systems and the overall objectives of the whole farm unit. If the Canadian livestock industry is to expand during the next decade as indicated by the Federal Task Force on Agriculture (23), forage as a feedstuff and possible cash crop is a prime contender for research and development -- totally mechanized handling being one of the assumed requirements of any system incorporating forage. As with all present agricultural systems, forage handling needs formally organized system studies, both comprehensive and complete, to assist the farm manager's decision making amidst the tightening interdependence of system components and the very narrow margin allowable for error.

The objectives of this thesis are outlined as follows:

(1) To compile existing engineering, nutritional, economic and agrometeorological data on forage handling.

(2) To computer simulate some of the present alternative systems applicable to the forage handling problem from field to exit from storage.

(3) To test the suitability of the GPSS programs in generating and costing alternate forage handling systems.

(4) To evaluate the cost sensitivity of sub-optimal machinery systems.

(5) To attempt to compare other possible mathematical methods of generating forage handling systems.

Because of the sheer size of the network and the mass of input data required, the analysis was limited to the Edmonton area where cost data were easily accessible, and to the alfalfa crop because of its relative importance in Alberta forage production and the available information as to its properties and characteristics. One of the general goals of this project was to construct the network and the technique of analysis so as to be adaptable to other regions, other crops and, other sets of input data.

2. LITERATURE REVIEW

There is a rather limited amount of literature available concerning forage handling from a systems standpoint although the basic theoretical concepts of the systems approach have at times been referred to in agricultural research. Systems engineering and systems analysis have been utilized extensively in industry for cost-benefit studies and consequently the bulk of available literature on the topic is industry oriented.

2.1 Definitions

The term "system" appears to have as many definitions as authors using it. Bonnicksen (14) said that "... A system can be defined as a set of things so related for some function to form a unity." Kershner's (73) definition is "A system is a collection of entities or things (animate or inanimate) which receives certain inputs and is constrained to act concertedly upon them to produce certain outputs, with the objective of maximizing some function of the inputs and outputs." Both a dynamic nature and human intent are bound up in this definition.

Similarly, the terms "operations research", "systems engineering", and "systems analysis" have been used with different intent or even interchangeably at times. Hall (56) lumped the first two together as "Application of rigorous methods of analysis to an entire system, rather than to just one operation to obtain an optimum solution ..." Kershner (73) stated that if the primary attention is placed on variation of the system composition, systems engineering is the term to use -- if on the variation of the system operation, operations research is the proper

name. Bonder (13) referred to the distinctions made by Edward Quade of the Rand Corporation: "The important thing to note is that (a) operations research involves the analysis of an existing system, (b) systems analysis concerns the comparison of alternative systems, and (c) systems research focuses on the development of systems planning procedures." It is the emphasis on comparison of alternative systems that was considered in this thesis.

2.2 The Systems Approach

Over ten years ago, Sammet (108) stated that "the systems concept, which views any complex entity or process in terms of the functions, inter-relationships, and integration of its parts in a unified whole is not new." The two levels of activity in a planned approach to systems studies are the same today -- systems analysis (involving definition, description, and study of processes and discovery of optimum relationships) and systems design and development (involving research and development of improved methods as translating analysis into plans of action).

The steps in systems analysis are effectively outlined by the same author as:

(1) Select performance goals and criteria (more on this later).

(2) Identify techniques in each production stage that together constitute an optimum organization. Identification can be done by experimental comparison (often a costly venture) or by modelling, "model" building or synthesis using existing engineering data. On occasion, variables with no expected significance on the end result can be factored out, although

the validity of simplifying assumptions <u>must</u> be tested later.

When and why is systems engineering used? Reitman (103) stated that "Systems engineering concepts should only be used when other methods and approaches have failed. Application of these concepts requires a team approach because of the complexity -- of the design problem, the techniques of solution and the user's operation of the system. No one person can be sufficiently able and adept in all three areas." A team of agricultural scientists, and in some cases policy makers, could adopt Nadler's (91) IDEALS concept for both preliminary stages of macro-system analysis and at subsequent levels of integrated systems research and work systems design (figure 1). Where few well-defined performance goals and criteria exist, and a "one-man" investigation of a system is undertaken, a more conventional approach is desirable.

2.3 Application of Systems Analysis Techniques

Given the fact that experimental comparison of forage handling systems could become a costly undertaking, initial comparisons of such systems might best be made using models of actual or synthesized cases -- mathematical models providing one of the better approaches to an unwieldy problem. According to Chestnut (26), "... in the solution of symbolic models, an analytic method is desirable because the exact answer is derived; a numerical method is acceptable where no analytic method exists; and the Monte Carlo solution is applied only if the other modes are either impossible or impractical. This is by no means a rare condition; Monte Carlo methods are being used more often these days as digital computer programs are available for repetitive probabalistic solutions." Peart, Isaacs and French (97) gave a brief resumé of

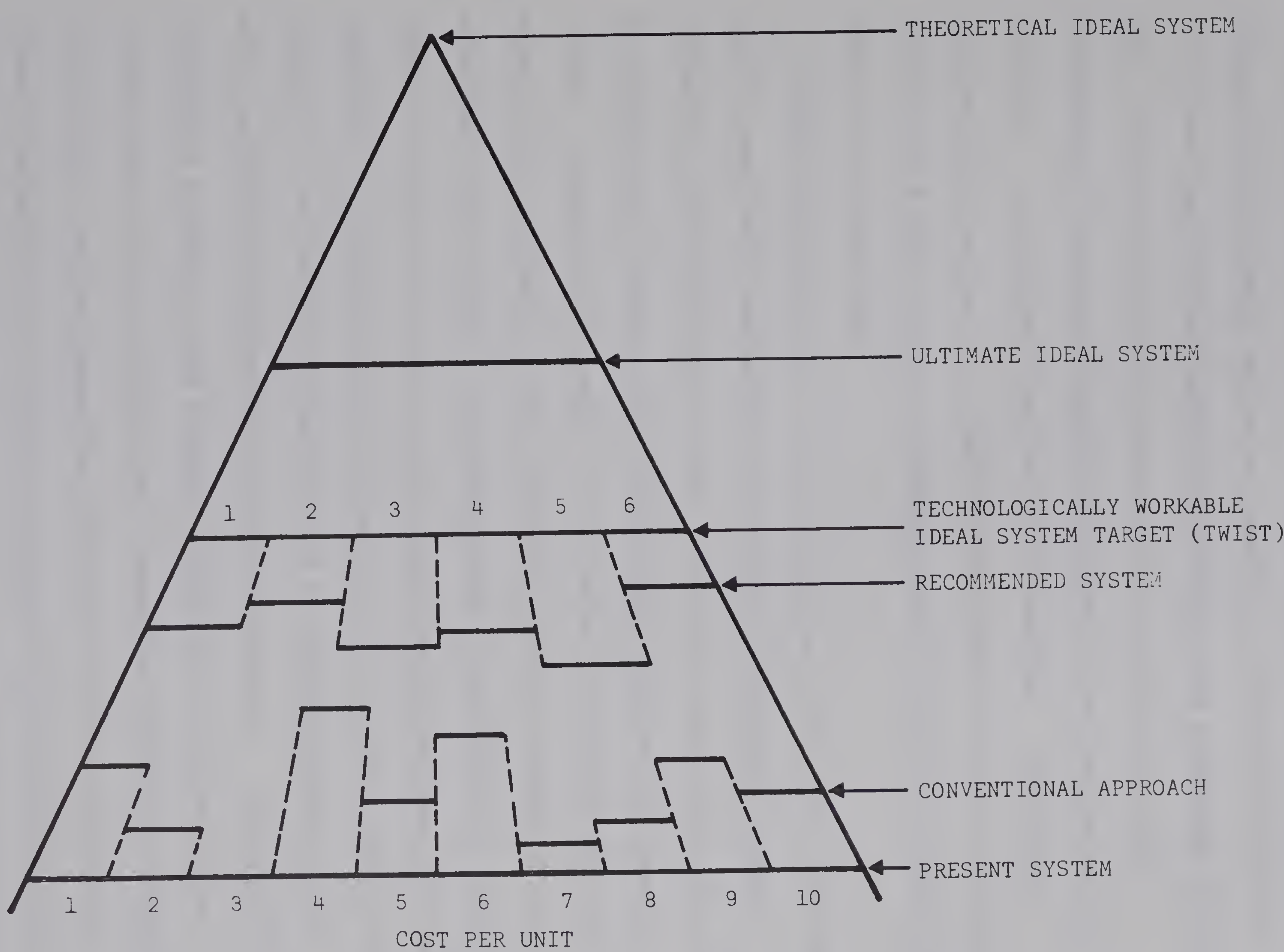


Figure 1. Levels of ideal systems as seen by Nadler (91).

some mathematical programming models and an application to optimization of a materials-handling system. Sowell and Link (116) reviewed mathematical programming and network analysis techniques, with some agricultural applications underlining strengths and weaknesses of each. Peart, Isaacs and French (97) stated that "A mathematical model encourages the concise and complete statement of the problem and the variables. It promotes objective decision-making. Subjective decisions will continue to be made in the original design of alternative systems, but a model capable of handling many variables allows many more factors to be quantified."

Linear programming (LP) and its extensions provide one of the most analytic and widely used methods available for optimizing resource allocation in an agricultural system. Dent and Casey (37) showed how LP has been and is being used for determining minimum-cost livestock rations. Expanding the limits of the system to the whole farm plan, MacHardy (82) and Anderson (2) showed how partial budgeting of farm enterprises and straight-line approximations of non-linear or curvilinear functions can be put into LP matrix form and maximum gross margin determined. The post-optimal information can be used to evaluate the accuracy of the above approximations and to indicate whether or not matrix alterations and program re-runs are necessary. MacHardy (84) developed a technique using Lagrange multipliers to determine the optimum size of field machinery where sequential operations are performed on the land. He also showed how this method could be combined with linear programming in an iterative procedure so that machinery could be sized in relation to the whole farm plan. More recently, MacHardy (83)

used product terms with integer programming to include sequential field operations and harvesting costs in separable programs where time is a resource competed for by other farm activities.

Another set of analytic methods can be generally entitled Network Analysis. As outlined by Sowell and Link (116), network analysis methods are concerned with scheduling of multi-activity processes taking into account the resource availability (notably time and capital), urgency, and topological relationships of activities. Both the critical path method (CPM) and the program evaluation and review technique (PERT) "require that the process being analyzed first be reduced to graphical form in an activity network". Studies conducted by Preston (99, 100) indicated that network analysis methods can be successfully applied to a farm machinery selection problem, handling time and cost parameters simultaneously. Preston's (99) shortest path network analysis (SPNA) routine (which has been successfully applied to comparison of alternative irrigation methods) can cope with step, curvilinear and other non-linear functions but only gives one sub-critical path and is therefore limited in the post-optimal information it can provide. Coupland and Halyk (30) applied network analysis to comparison of forage handling alternatives using data applicable to the Quebec area.

Hunt (65) emphasized that maximization is not always accomplished by minimizing costs. "The need for timely operations is rather a unique economic constraint on the farm machinery system." Using a series of equations relating economic and physical parameters of the problem, Hunt's method of machinery selection required some initial guesswork and an iterative procedure for improving the solution if these guesses were incorrect. Regional timeliness factors ("decimal

reduction of quantity and quality of the potential crop per hour of machine operation") were applied to any given acreage, yield and crop value. Stapleton's (117) method used timeliness functions to produce charts comparing different systems. A simulation model developed in England by Donaldson (42) assessed harvest machine capacity while allowing for weather risk. Using the Monte Carlo approach, MacHardy (81) formulated a method of calculating harvesting costs for weather-dependent harvest operations where penalties vary inversely as the rate of harvest. Von Bargen (7) conducted a systems analysis of hay harvesting in east central Nebraska, in which he applied the Monte Carlo method to baling of alfalfa hay, generating cumulative probability curves for time needed to complete the baling. The major problem in applying a simulation sampling technique to weather functions is in determining what constitutes a 'work' and a 'non-work' day as well as the penalty in time and product loss resulting from unfavourable weather.

Link and Bockhop(78) developed a method for scheduling of sequential field operations using a systems-analysis procedure. Given a system performance prediction, adequate economic and weather information, and "acceptable risk criteria", cumulative probability curves were generated from historical weather data for 'arrival' and 'completion' dates of the sequence in question. The particular 'holding period' depended on the interaction of weather and crop-machine parameters.

The simulation of weather may be done at some preliminary point followed by a more analytic analysis of the entire system under study. Russell (106) used a weather simulation program based on MacHardy's (81)

method, and on data compiled in a 1968 student laboratory experiment on combine harvesting. The class concensus of acceptable weather criteria and penalties associated with unfavourable weather were used to generate a penalty cost curve associated with combine capacities. Then the acreages, capacities, fixed costs, operating and penalty costs, and optimum harvesting period length were related to the separable programming analysis of the whole farm plan. A sensitivity analysis indicated that a ±10% change in the penalty cost curve would not appreciably influence the farm manager's optimum selection of machine capacities. Baldwin (6) first analyzed the weather data in relation to sugar cane cropping periods and subsequently inserted these durations into a CPM-type, time-scaled network used for resource allocation, project planning and management.

2.4 Prognosis for Systems Engineering in Agriculture

Coales (28) foresaw definite use of systems engineering in agriculture. To make the systems approach fully effective, simulation of the processes is necessary; before simulation is possible, mathematical models of the processes need to be developed; before modelling can be attempted, a means of measuring the essential variables must be developed. Coales further stated that since agricultural systems are so dependent on environment, "... better prediction of environmental conditions is an essential requirement for better planning and control". However, experience has shown that a useful start can be made with very rough measurements and quite often approximations can be made to greatly simplify the model.

Although some development of systems analysis techniques has occurred, a rather limited number of applications have been made to forage handling systems. Further study and analysis of stochastic variables and simulation models are needed (7, 28, 78, 81, 97, 116).

2.5 Cost-Benefit Simulation and GPSS

Donaldson and Webster (43) used a simulation approach to whole farm planning. The method used random numbers to select and size farm enterprise activities according to the resource restrictions. Using a computer program, many different farming programs were set up and the top twenty solutions printed out for the user to subjectively analyze. Theoretically, if the number of iterations requested was large enough, the optimal solution would be included in this top twenty.

The author selected a similar approach to the problem of selecting a forage handling method. An I.B.M. program package called GPSS/360 (52) -- acronym for General Purpose Simulation System -- was applied to a network of forage handling alternatives. A program was written to randomly select routes through the network, duplication being possible. For each pass through the network, the nodes of importance were noted, arrow coefficients calculated, and cumulative statistics stored -- enroute from initial to terminal nodes. Given the probability of selecting the least likely route, the required number of selections could be determined to ensure, with a given probability, the selection of that route at least once. Both stochastic and analytic relationships were included in the one cost-benefit simulation.

3. SELECTION OF METHODOLOGY

3.1 Determination of the System Boundaries

Every system found in agriculture is a sub-system of some larger system, acting and interacting continuously. Because forage handling systems are usually part of a farm enterprise, and this in turn a segment of a farm firm, delineation of system boundaries is somewhat arbitrary. Does the forage handling system begin with cutting the forage in the field, or does it start with the preparation of a seed-bed for the nurse-crop? Similarly, does the system end with the forage in storage, or does it actually terminate with the sale of the animal product? Resources of time and capital are limited, and all enterprises on the farm compete for both. The optimal forage handling method cannot be decided upon without prior knowledge of the overall objectives of the firm. Given partial information as to system overlap, integration and/or priority, qualified guidelines may be formulated.

The end points of this simulation were somewhat arbitrarily chosen as (1) forage standing in the field at its 'optimal' point of development and (2) forage as it leaves the storage unit. Extending the study to include planting, fertilizing and related operations prerequisite to a fully established stand of forage would involve simulation of one to two years of weather, and require consideration of other cropping enterprises and resource requirements. To extend the boundaries of the study to include feeding of the forage would require a knowledge of the number, type, age and rations of the animals using the forage. Such extensions would magnify the complexity of the network as well as hamper any attempt to draw some general conclusions about the network of system alternatives.

Edmonton and vicinity was the only area included in the analysis.

Alfalfa was the only forage crop considered. Data and parametric relationships, although not comprehensive, were most easily available for alfalfa, the one forage crop that has come in for more intensive study than has any other in Canada. In addition, alfalfa is the most important forage crop grown in Alberta. The 1966 Census showed that alfalfa and alfalfa-grass mixtures accounted for over 1.3 million acres or close to 47% of the total tame hay area. In Census Division Number 11 (see figure 2), over 52% of the tame hay acreage was devoted to alfalfa and alfalfa-grass mixtures (see table 1). Sales of hay and fodder accounted for a significant amount of farm sales.

3.2 Method of Analysis

As intimated in section 2.3, a simulation approach has some merit when dealing with a stochastic variable such as weather. The SPNA routine, with certain additions or modifications made in the program, might present one possible way of combining non-linearities and probabilities into one network analysis problem. Some limitations inherent in the routine present problems. First of all, the sensitivity analysis must be conducted by successive re-runs. Secondly, this routine requires that all arcs or arrows in the network have coefficients evaluated for them before the shortest route can be found. As a result, all possibilities and input combinations that may arise must be incorporated into the network so as to obviate the need for a looping procedure.

Brück and Van Elderen (19) used a simulation language called DYNAMO (DYNAmic MOdelling) to simulate field drying of ryegrass, at

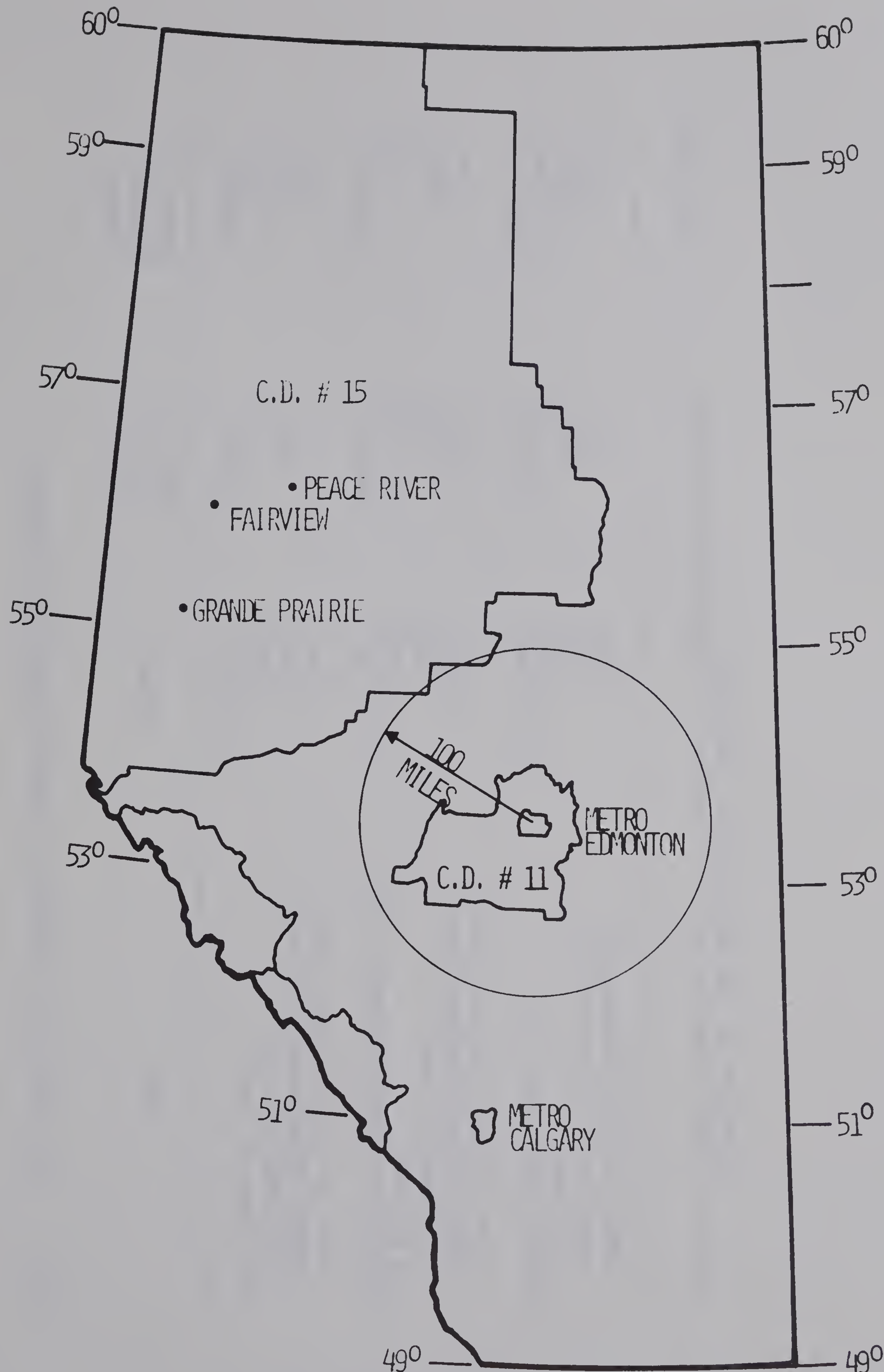


Figure 2. Alberta's major forage-producing census divisions.

TABLE 1. SOME CENSUS DATA RELATED TO FORAGE PRODUCTION IN ALBERTA[a]

Item	Alberta	Census Division Number 11	Census Division Number 15
Total tame hay (ac.)	2,937,983	374,546	476,894
% of tame hay area	100.0	12.7	16.2
Census farms reporting (no.)	42,770	5,937	5,554
Acres per farm (nearest acre)	69	63	87
Alfalfa and alfalfa mixtures (ac.)	1,374,297	190,778	113,712
% of same	100.0	13.9	8.3
% of tame hay area	46.8	52.7	23.8
Census farms reporting (no.)	25,801	3,700	2,338
Acres per farm (nearest acre)	53	52	49
Hay and fodder sold ($)	10,730,800	665,450	5,226,350
% of same	100.0	6.2	48.7
Census farms reporting (no.)	9,330	1,054	2,341
Sales per farm (nearest $)	1,150	631	2,233

[a]Source: Canada, Dominion Bureau of Statistics, 1966 Census of Canada, Vol. V: Agriculture, Catalogue No. 96-610 (Ottawa: May 1968).

Wageningen, Holland, incorporating many meteorological variables into the model. Since the weather records available for the Edmonton area are far from detailed enough for this set of equations, the above model was set aside. The GPSS package mentioned in section 2.5 was successfully used by Russell (106) in simulating a thousand years of wheat harvesting. The author chose this GPSS package because it was easily available, and the built-in versatility would permit calculation of set cost equations or setting of logic patterns as well as manipulation of probabalistic functions. Where empirical data were either missing or unavailable, subjectively determined data were inserted. The analysis of the results then indicated that either empirical study was needed in the area or the material used did not significantly influence the choice of an optimal system.

4. THE COMPUTER SIMULATION PROGRAM

4.1 Format and Explanation

Beginning with the simplified flow chart in figure 3, a GPSS program, geared to a particular area, can be constructed incorporating only the sequences pertinent to that region. The units of traffic used throughout the program were years, called "transactions" in the GPSS/360 terminology. As each year of forage handling proceeded through the program, a record was kept of the current relative time in days. Figure 4 presents a condensed and simplified explanation of the major steps in the general program. Block and non-block entities make up the program, transactions passing through the former having their numerical or logical values altered by the attributes of these blocks. Except for a few special cases, all values generated and calculated in the program were integer quantities. Following the simulation of the last year, the program printed the resulting frequency distribution as programmed. The drawback lay in the inability of the analyst to trace specific values in the tables back to pertinent network routes. Therefore, the author elected to conduct the simulation and collation of resulting information in separate steps. For each year simulated, a vector of important nodes, intermediate values and final values was stored, then transferred to magnetic tape. After the entire simulation was completed, FORTRAN-IV programs were used to rank the transactions according to a cost criteria and to tabulate and plot values versus selected routes.

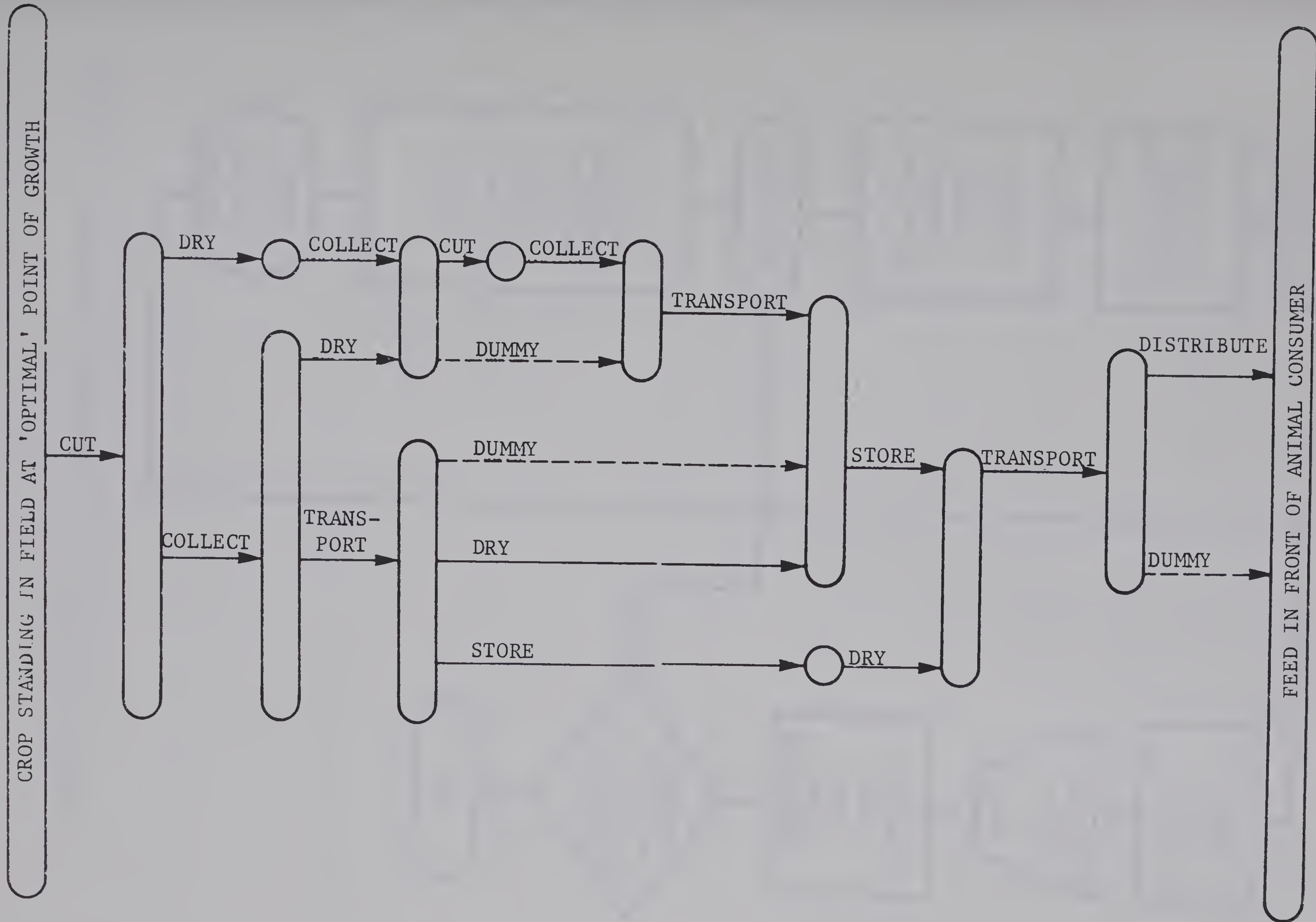


Figure 3. General network flow-diagram of alternative processes in forage handling.

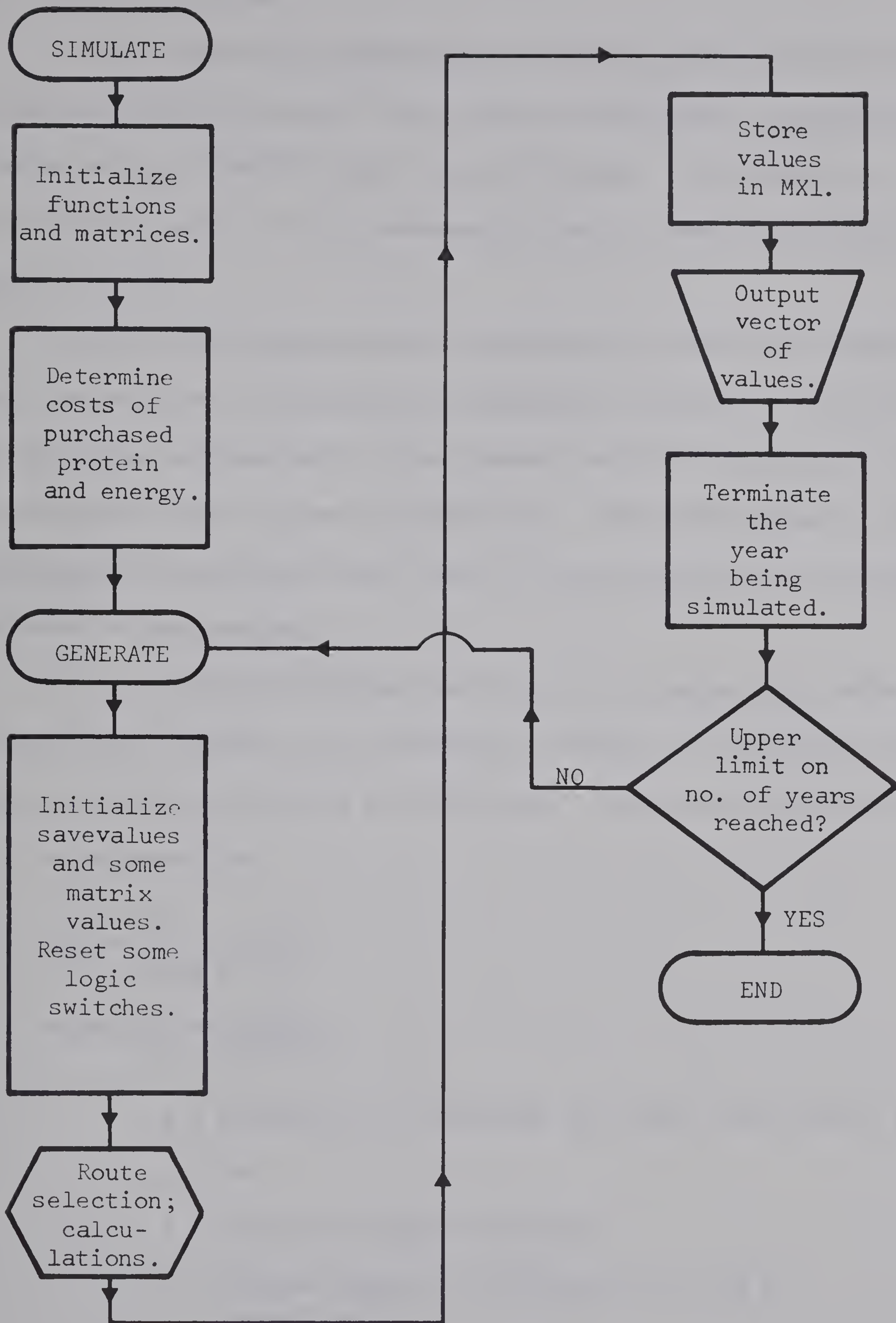


Figure 4. Simplified flow chart of the simulation programs.

4.2 Route Selection

As the transaction progressed through the network, it encountered nodes with multiple exits. The exiting arrow chosen was selected at random using a TRANSFER block in the PICK mode. Consequently, alternative routes did not necessarily have the same probability of being selected.

The GPSS/360 package permits weighting the selective transfer block provided only two alternatives are presented. Therefore, by increasing program size and complexity, the program could be altered to select each alternative route with equal probability. One disadvantage is that expansion of the network would lead to a multiplication of changes required in the program.

Prior to actually running the simulation program, the number of transactions required to be reasonably confident of selecting each route at least once should be determined. The negative binomial model can be expressed as

$$Pr_k = \sum_{i=k}^{N} {}_N C_i \, p^i q^{N-i}$$

where $${}_N C_i = \frac{N!}{i!(N-i)!}$$

p = probability of choosing the least likely path, x

q = 1-p

N = number of random selections

k = minimum number of occurrences of x in N selections

Pr_k = the desired level of probability of k occurrences of x in N selections

According to Steel and Torrie (118), normal approximation will apply as p becomes very small and k remains relatively small. A small computer program was written to iteratively determine N given p, k (set equal to 1), and $Pr_k \pm \varepsilon$ where $\varepsilon = 0.001$. Table 2 indicates the approximate number of selections required under different network conditions. The first sub-section of the network had 224 alternative routes, with the probability of randomly selecting the least probable route of 0.00261. The required number of transactions for 90% probability was 883. For the second sub-section of the network, 6720 alternative routes existed with the least likely having a probability of 0.000083 of being selected. By consolidating many of the minor route variations, the number of routes could be reduced to 1344. Even with such a reduction, the required number of transactions for 90% probability was 4640.

4.3 Program Subdivisions

These transaction requirements indicated that the program would have been difficult to handle adequately in one computer simulation. The program listed in Appendix G represented less than one-third of the entire network yet used three to four minutes of computer time to complete the assembly phase alone -- any transactions taking additional time.

Note: Because normal allocation of computer core storage for entities proved inadequate for some types of entities, the REALLOCATE *card was used to give additional core to* COMMON, BLOCK *and transaction entities.*

TABLE 2. TRANSACTIONS REQUIRED AS CALCULATED FROM THE NEGATIVE BINOMIAL PROBABILITY FUNCTION

p	N for Pr $\pm$ ε		
	Pr = 0.90	Pr = 0.95	Pr = 0.99
0.1	22	29	44
0.05	45	59	90
0.04	57	74	113
0.03	76	99	152
0.02	114	149	230
0.01	230	300	460
0.005	460	600	900
0.00261[a]	883	1,152	1,766
0.001	2,300	3,000	4,600
0.000496	4,640	6,050	9,280
0.0001	23,000	30,000	46,000
0.000062	27,820	36,290	55,640

[a]Note: The last five lines give only approximate values of N.

In view of the large requirements for core storage and execution time, the entire network was split into segments. It was considered that a logical division could be made between direct cut and field cured systems. The first computer program incorporated dehydrated alfalfa and high moisture silage, while the second included wilted alfalfa silage and haylage. Those sections of the network dealing with bales, wafers, pellets and bulk hay were not simulated and analyzed because of general time limitations.

5. PROGRAM DATA AND DATA MODIFICATIONS

5.1 Input Data Formats

Some of the input data remained constant throughout the simulation and were applicable to all subdivisions of the program. Labour cost, for example, was set at \$2.00/hr. In the case of neighbour exchange work, a lower rate might be more realistic. However, all labour was charged at the same rate, whether full-time or casual, owner labour or hired labour. Rest allowance figures are another example. Rest allowances for machine-controlled and for manual or demanding tasks were maintained at $12\frac{1}{2}\%$ and 30%, respectively, as used by Dilke (39) and by Devine and Wright (38).

Values of certain program parameters were changed from pass to pass through the network. A subjective decision was made as to which parameters should be approximated by linear approximations or linear regression equations and which should be approximated by a number of fixed but alternative values. For example, a number of specific machines in a given category could be approximated by one linear regression equation or could be inserted in the program as a set of alternative units, one to be selected at random. Where interaction of parameters was unknown, the parameter level was dependent on management, or had been successfully approximated by other researchers as a constant, the following approach was considered to be warranted:

> Where the input datum was within a specified range, a point in this range was randomly selected.

5.2 Cost Evaluation of Forage

Some constants could be calculated then inserted into the program or could be calculated during the first pass through the network. The latter approach was taken in determining cost figures for digestible protein (DP) and digestible energy (DE), these two coefficients used throughout the simulation to evaluate crop maturity, weather losses, mechanical field losses and storage losses. The "Petersen" method of cost evaluation of feeds as revised by Morrison (90) was used. The difference in cost between a pound of the cheapest protein source and an equivalent weight (DE basis) of the cheapest energy source was attributed to the extra protein in the protein source (see Appendix I for equations used).

With reference to table 3, if urea was the cheapest protein source and wheat the cheapest energy source, purchased protein cost $37.37 per ton of DP and purchased energy cost $8.34 per kilotherm (kth) of DE. If soybean meal was the cheapest protein source due to limitations on the use of urea in the ruminant diet, purchased protein cost $102.89/ton DP and purchased energy cost $5.84/kth DE. For this simulation,soybean meal and wheat were chosen.

Growth data on forage crops in the Edmonton area appears limited. In New York State, Millier and Rehkugler (88) were able to obtain growth functions with corresponding protein and energy values in their simulation of forage handling. Care must be taken in using such growth functions since growing patterns vary substantially from region to region and season to season depending on cultural practices, managerial expertise and seasonal weather. In lieu of growth functions, constant

TABLE 3. FEEDSTUFF AND COST COEFFICIENTS[a]

Feedstuff	Wet Matter Basis					100% Dry Matter Basis	
	Cost[b] ($)	Dry Matter (%)	Total Protein (%)	DP (%)	DE (kcal/lb)	DP (%)	DE (kcal/lb)
Feed grade urea	105.00/T.		281.0		0		
Hard spring 'feed' wheat	0.95/bu			12.4	1,620		
Soybean meal, solvent, all analyses (44%)	112.00/T.			43.1	1,560		
Alfalfa hay, pre-bloom		89	19.3	13.3	1,093	14.9	1,228
Alfalfa hay, early bloom		90	16.6	11.6	1,048	12.9	1,165
Alfalfa hay, mid bloom		89	15.2	10.6	990	11.9	1,110
Alfalfa hay, late bloom		88	14.0	9.5	958	10.7	1,090
Alfalfa hay, past bloom		91	13.9	8.9	971	9.8	1,067
Alfalfa meal, dehydrated		92	16.7	11.6[c]	1,080	12.6	1,174
Alfalfa silage		30	5.3	3.4	360	11.3	1,200
Alfalfa silage, wilted		36	6.4	4.1[c]	400	11.4	1,111

[a] Except for urea, all feedstuff analyses were taken from a NRC publication (92).

[b] Source: A feed cost sheet for Winter, 1970 as used in an Animal Nutrition Course at the University of Alberta.

[c] The ratio of DP:TP was assumed equivalent to that for pre-bloom alfalfa hay.

yields were used in this simulation with a growth-maturity factor to roughly evaluate the economic importance of various losses and to determine whether growth-curve functions would appreciably affect the optimal choice of forage handling system. A dry matter yield of one ton per acre was assumed for both cuttings -- the field located an arbitrary distance of one mile from storage. In actuality, the second yield datum is likely to be less than the first depending on the stage of development at first cutting and the nature of the subsequent weather.

For this analysis, the late bud to early bloom stage of the alfalfa in the grass-legume mixture was taken as being the optimal point for cutting -- optimal in terms of feeding value per acre. Fulkerson et al. (51), in studies in Ontario, showed that cutting at this recommended stage would result in the harvest of only 70% of the dry matter but would produce 94% of the crude protein. The protein and energy coefficients as given by NRC (92) for pre-bloom alfalfa hay were taken as a better indicator of feeding content of uncut, early bloom forage than the coefficients for early bloom alfalfa hay. The reason for this assumption is that about 70% of the protein in the alfalfa plant is contained in the leaves (98), and leaf losses are substantial for any haying system incorporating field curing of alfalfa hay. Ingalls (66), in a note on forage quality, stated that harvesting alfalfa in the first bloom stage results in increased dry matter intake by animals, increased energy value per pound of forage, increased protein per pound of forage, and increased protein and digestible energy yield per acre. "Each day's delay in harvesting of first cut hay results in 0.2 to 0.5 percentage

points decrease in digestibility." Of course, this figure will change from species to species and over time. According to a United Grain Grower's publication (33), Ingalls' rule of thumb is that feeding value per acre of first cut forage drops more than 1% per day from early flowering to mature stages. This 1% figure was used as a growth-maturity factor in the simulation for both cuttings and over the entire cutting period -- a deviation from reality likely of limited consequence in comparison to other aspects of the cost-benefit analysis. Although dry matter yield was held constant, the approximate change in feeding value was noted and converted to a penalty cost.

5.3 Operating Costs of Power Units

Fuel consumption data are dependent primarily on the task the power unit is assigned. Southwell's (114) 1966 analysis of tractor relative engine efficiencies was used as a basis for establishing fuel consumption data. He used the following datum and equation:

specific fuel consumption = 0.45 lb/hp-hr

$$\text{engine efficiency} = \frac{0.45\ \text{lb/hp-hr}}{\text{lb/hp-hr at max. pto at rated speed}}$$

Given fuel density figures taken from Barger et al. (8), and Southwell's relative engine efficiencies,

$$\frac{\text{gal}}{\text{pto hp-hr}} = \left(\frac{100\%}{\%\ \text{rel. eng. eff.}}\right)\left(\frac{0.45\ \text{lb}}{\text{pto hp-hr}}\right)/\frac{\text{lb}}{\text{gal}}$$

One factor not taken into consideration in the program was that for some field and farmstead operations, within the sequence chosen for any one transaction, fuel consumption will drop because of operation at other than maximum pto hp. Another factor not considered in this program was the different engine efficiencies one might expect for small

TABLE 4. FUEL COST AND CONSUMPTION DATA

Fuel Type	Edmonton Cost ¢/gal[a]	Relative Engine Efficiency %	Fuel Density lb/US gal	API at 60^{o}	Consumption US gal/pto hp-hr
Gasoline	$21\frac{1}{2}$	75 - 96	5.98 - 6.15	66 - 60	0.076 - 0.101
Diesel	18	80 - 116	6.87 - 7.12	40 - 34	0.055 - 0.082
LPG[b]	14				0.091 - 0.120

[a]Imperial gallons used.

[b]According to the 1969 ASAE Yearbook (48), average fuel consumption for LPG tractors under varying loads is approximately 1.20 times as large as that for gasoline tractors.

gasoline engines, the assumption being that any error introduced would have a negligible effect on the total operating cost for the system. Table 5 appears to indicate that the lower limits on fuel consumption are slightly higher than one might expect, if estimated values used by Maish, Cuykendall and Hasbargen (85) are reasonably accurate. Lubrication costs are approximated as 15% of the fuel cost, as suggested in the 1969 ASAE Yearbook (48). Fuel consumption for farm trucks was set at six mpg when travelling full or operating under load, and eight mpg when travelling empty or idling. These figures were suggested as a rough guideline by a local supplier of farm trucks.

Transport speeds, both empty and loaded, were introduced in the program as constant for any one transaction but varying within a range for the entire simulation. However, the type of operator and the roughness of the terrain would influence these speeds. Subroutine SPEED selected a point at random in the given range (see table 6) whenever transport speeds were required.

Custom transporting was compared to owning transport units and hiring drivers -- two different arcs in the network. A custom rate of $4.00/hr for a 35 to 40 hp tractor plus driver and a figure of $8.00/hr for a farm truck plus driver, hired on a work-day basis, were used. The former figure was chosen after studying a survey of custom charges for various sizes of tractor units in the Ponoka County (32), although the rate would be significantly higher for a full-time custom operator. Thus, forage handling systems using custom transporting facilities would be given a favourable bias if any bias occurred.

TABLE 5. COMPARISON OF FUEL CONSUMPTION ESTIMATES

Tractor pto hp	Gasoline Consumption at $\frac{0.076 \text{ gal}}{\text{pto hp-hr}}$ gph (US)	Diesel Consumption at $\frac{0.055 \text{ gal}}{\text{pto hp-hr}}$ gph (US)	Estimated Gasoline Consumption[a] gph (US)
30	2.28	1.65	1.7
40	3.04	2.20	2.2
45	3.42	2.48	2.5
55	4.18	3.02	3.0

[a]Source: Maish, Cuykendall and Hasbargen (85).

TABLE 6. MATRIX OF TRANSPORT SPEEDS

Transport Unit	Speed Range Loaded		Speed Range Empty	
	minimum mph	maximum mph	minimum mph	maximum mph
Tractor	8	15	10	20
Truck	20	30	25	40

Where some mechanical component in the system required fuel oil, the Edmonton cost of 17½¢/gal was used. Electricity for farms in the Edmonton area costs about 1¼¢/kwh. Conversion figures of 0.7452 kw per hp and 2/3 electric hp per internal combustion hp (123) were applied when required.

5.4 Amortization and Repair Costs of Power and Transport Units

Regression equations were used to calculate initial fixed costs of both power and transport units. A salvage value of 10% was deducted from the initial cost and the remainder amortized on a straight-line

basis as allowed by the 1969 Farmer's and Fisherman's Tax Guide (21). Interest rate was included at a constant 8%. A machinery insurance rate of 0.5% and a housing rate of 1% were used.

Because required pto hp and necessary transport capacity were considered as parameters having a range of possible values, a regression analysis of available cost data would provide the necessary coefficients to find an initial cost at any point in the permitted range. Table 7 shows the regression equations used for finding initial costs of power and transport units; a more extensive table is available in Appendix D.

Repair and maintenance costs were calculated on an hourly basis as a percent of purchase price, as outlined in the 1969 ASAE Yearbook (48) and as used in several analyses, the systems study of Meyer, Frisby and Martz (87) providing a good example. Where specific repair cost data were unavailable, a subjective decision was made as to which machine most closely resembled it in terms of machine life and hours of use per year.

TABLE 7. REGRESSION EQUATIONS USED TO CALCULATE THE NEW COST OF POWER AND TRANSPORT UNITS

Gasoline tractors:	\$cost	=	-\$399.73	+	$\left(\frac{\$126.58}{\text{pto hp}}\right)$(pto hp)
Diesel tractors:	\$cost	=	\$249.64	+	$\left(\frac{\$121.06}{\text{pto hp}}\right)$(pto hp)
Farm trucks:	\$cost	=	\$2,545.50	+	$\left(\frac{\$457.89}{\text{T. payload}}\right)$(T. payload)
Farm wagons (less tires):	\$cost	=	\$40.17	+	$\left(\frac{\$29.08}{\text{T. payload}}\right)$(T. payload)
Self-unloading forage boxes:	\$cost	=	\$1,114.14	+	$\left(\frac{\$1.37}{\text{ft}^3}\right)$($\text{ft}^3$ capacity)
Custom truck boxes (installed):	\$cost	=	\$208.22	+	$\left(\frac{\$0.71}{\text{ft}^3}\right)$($\text{ft}^3$ capacity)

6. FORAGE SYSTEMS WITH NO FIELD CURING

6.1 Program Inputs

6.1.1 Initial method alternatives -- Western Canadian farmers harvesting forage directly without allowing any field curing of the forage are limited to a high-moisture silage or a dehydrated alfalfa product. Such direct-cut methods in the Edmonton area utilize some kind of forage harvester. For this simulation, four different possibilities were considered. The pull-type, flail-type forage harvester is in a class by itself in terms of initial capital outlay, power requirements, and resulting state of the forage. Pull-type forage harvesters with cutter bars were subdivided by type of cutterhead (i.e., cylinder or flywheel) since the price differential was considerable. On the other hand, all of the few distinct types of self-propelled forage harvesters were grouped.

The first section of figure 5 and all of figure 6 show the network alternatives and subdivisions included in the first computer program (see program in Appendix G). Although the left-to-right flow indicated by the arrows is primarily a decision flow and not a time flow, it does not obviate the possibility of loops and tests in the program at intermediate points.

Note: A test was made at node 80 as to which type of material was previously chosen at node 28, going directly to node 1,000 if dehydrated alfalfa or to node 81 if high-moisture silage. Thus there were 224 alternative routes with the least likely having a probability of 1/384 or 0.00261. Table 2 can be checked to determine the minimum number of transactions required for a given probability of choosing the least-cost system alternative.

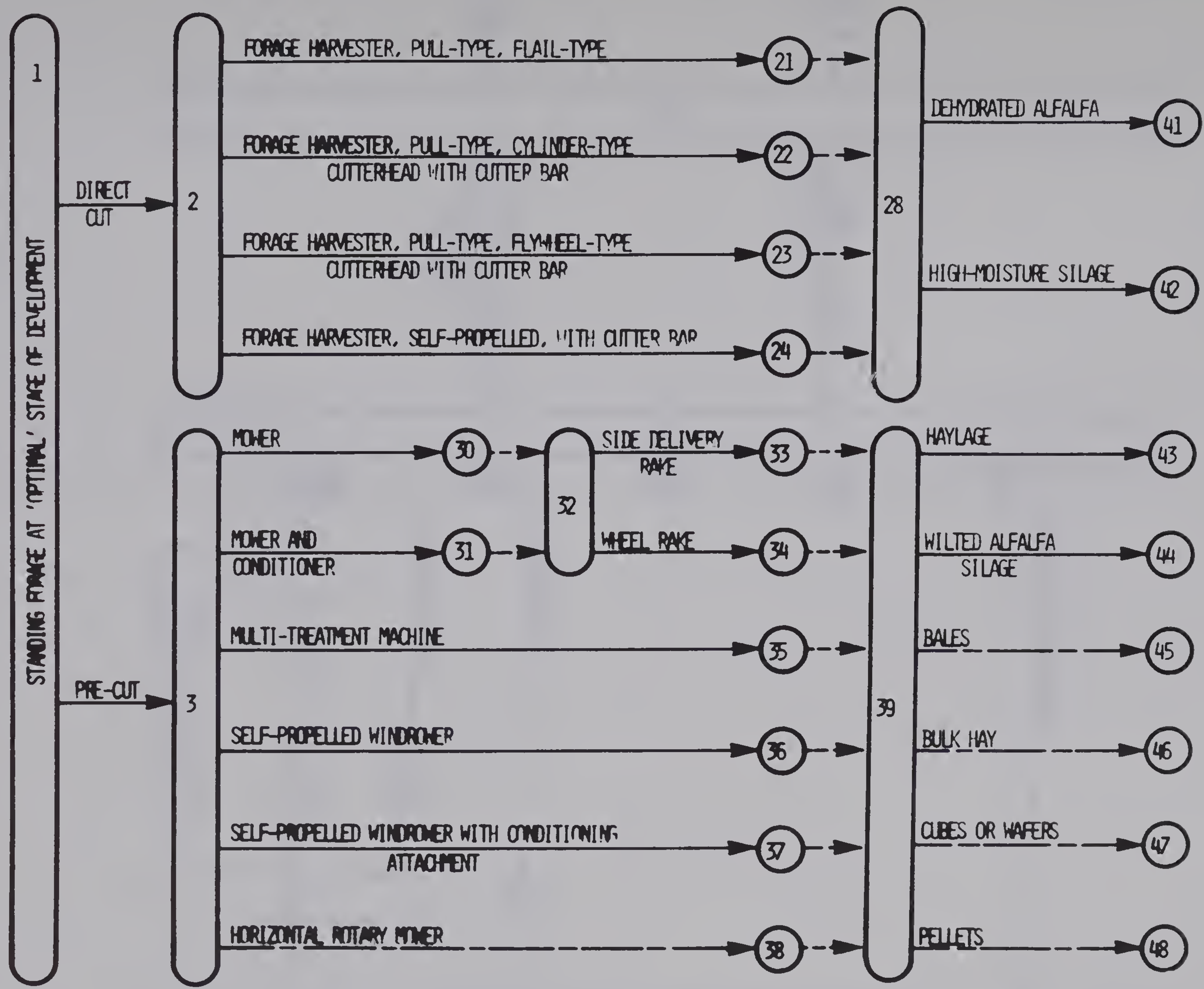


Figure 5. Initial network section.

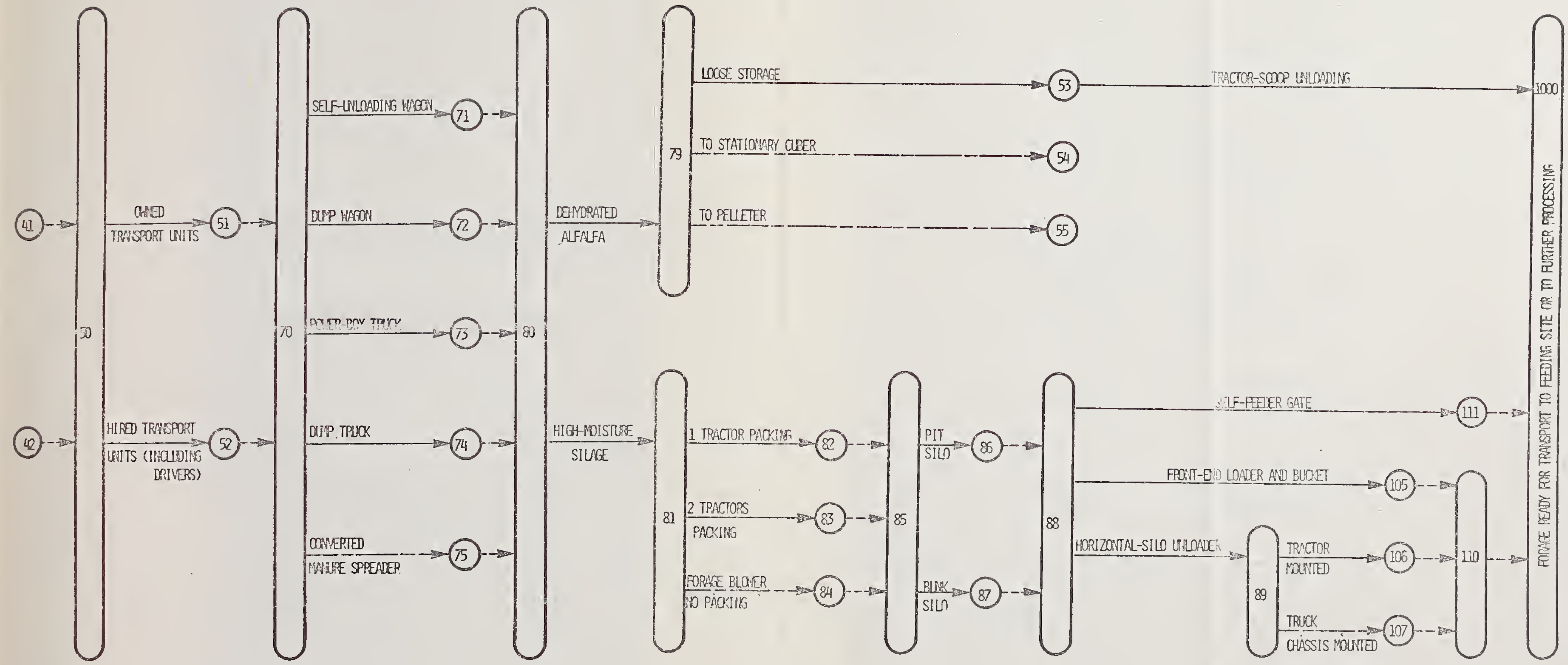


Figure 6. Silage and dehydrated alfalfa network section.

As in SPNA, the node numbering system was purely a matter of notation and did not require a set pattern. Also, dummy arrows were introduced to ensure uniqueness of definition (as required in CPM or SPNA) -- not because the simulation required them but because subsequent analysis could then trace system components without difficulty. Broken lines were used for alternatives arbitrarily excluded from this analysis. Perhaps these alternatives would be worth considering for special situations where other enterprises could make use of the same equipment.

6.1.2 Some Functions -- FUNCTIONS 1,2 and 3 are dollar-cost functions for three-phase electric motors, the cost figures representative for the Edmonton area. FUNCTIONS 4 and 5 are also dollar-cost functions, but for small gasoline engines and single-phase electric motors using the quotations from two Edmonton distributors. Discrete functions were used because hp ratings other than those listed are either unavailable or not normally requested in Edmonton.

Note: Since GPSS FUNCTION *cards are not block entities, they are unaffected by and do not affect the transaction flow. Functions can be placed anywhere in the program but must precede the first block referencing them -- thus the placement of functions at the outset of this program.*

Loss FUNCTIONS 6 and 11 were taken from Weller's (127) tables and are given in table 8. It should be noted that these tables reflect mean, rather than an entire range of values. Since the losses were to be stored as integer values, there would be little advantage in using continuous over discrete functions.

TABLE 8. DRY MATTER LOSSES FOR SEALED BUNKER SILOS

Moisture Content % w.b.)	Field Losses (% DM)	Seepage Losses (% DM)	Fermentation Losses (% DM)	Surface Losses (% DM)	Total Losses (% DM)
85	2	8	11	2	23
80	2	5	10	2	19
75	3	2	8	2	16
70	3	1	7	4	15
65	4	0	9	5	18

Note: FUNCTIONS 8 *and* 10 *deal with halfword* SAVEVALUE *entities that have one value or a range of possible values. After each transaction is generated, these entities have their values reset by the initializing subroutine. In the* INITL *subroutine, an integer in the given range* (FUNCTION 10) *is randomly selected, then added to the lowest value* (FUNCTION 8) *to give a constant value for the duration of the year being simulated.*

<u>6.1.3 Forage harvesters</u> -- Moisture content of direct-cut forage was given a range of 72% to 80% wet basis in this analysis. This range includes values observed by Pedersen and Buchele (98), Horne and Kjelgaard (64), Shepperson and Corrie (111), and Dudar (44). According to Bainer, Kepner and Barger (5), actual maximum working capacity of the forage harvester will ordinarily be somewhat less than the theoretical maximum indicated by the specifications. Difficulties arise in maintaining a uniform feed rate because of field design, crop density and care in harvester maintenance. Again, according to the same

authors, the shearing or cutting of the forage is the largest single power requirement in operating a forage harvester. Cutting energy requirements vary with the type of material, moisture content and length of cut. The ASAE Yearbook (46) suggests 1 to $2\frac{1}{2}$ hp-hr per ton of dry matter for grass silage with a desired theoretical length of cut of $\frac{1}{2}$ inch. Work at Purdue University, referenced by Bainer, Kepner and Barger (5), indicated that required energy becomes more a parabolic function of moisture content as the fineness of chop increases. Roughly approximating these graphed values, a three-inch theoretical length of cut should require from $\frac{3}{4}$ to $1\frac{1}{4}$ hp-hr per ton of dry matter. Because length of cut is not a critical factor in any of the systems considered in this program, the longest length of cut was chosen. For harvesters with a cutterhead, this length will theoretically be in the order of three inches. Shepperson and Corrie (111), among others, have found that the actual length of cut exceeds the theoretical to some extent. Therefore, the length of flail-cut forage may not differ greatly from cutterhead-chopped material. The figure of $1\frac{1}{4}$ pto hp-hr/ton DM was used as a constant throughout this part of the simulation in determining the power-dependent rate of harvesting for a given size of power unit. This figure was compared to the width-dependent rate of harvesting and the limiting one used as a constant for the transaction in progress. Forage harvesting speeds used in the latter calculations ranged from 3.3 to 4.6 mph as given in The Grain Grower (122). In both rate calculations, field shape and size, rough terrain, driver expertise and mechanical delays were taken into account by means of an efficiency figure. The ASAE Yearbook (48) gives a range of 50% to 75% efficiency for forage harvesters.

Self-propelled harvesters require a good proportion of their total horsepower for locomotion and therefore the width-dependent rate of harvesting will likely be the limiting one.

6.1.4 Weather analysis -- The single criterion used for establishing work and non-work days was field tractability. Although one might expect to cut forage before crop land is dry enough to cultivate, three other factors to consider are:

(1) if the sod is quite wet, tractor wheels may 'chew up' the sod.

(2) wet forage and wet soil together may tend to plug or gum sickle-bars.

(3) forage that is cut and laid on top of moist to wet ground may absorb moisture, or at least dry at a slower rate, thus increasing drying time requirements and increasing the likelihood of weathering.

Rutledge (107) studied field tractability probabilities in the Edmonton area on two different types of soil. "The soil moisture content was used to determine whether tillage operations were possible or not." In his analysis of historical weather data (1921 through 1965), Rutledge labelled a particular day as a non-work or a 'bad' day if "... moisture content in any one of the top three zones was above 95% of field capacity or if there was snow on the ground".

For this cost-benefit study, Rutledge's (107) tables of observed 'good' and 'bad' days were analyzed and the resulting cumulative frequency distributions inserted into the GPSS program as continuous

functions. The two hay harvesting periods used by Russell (106) for the Edmonton-Red Deer area were (1) June 20 to July 15, and (2) August 15 to September 18. These two periods were used in analyzing the data but further analysis was conducted to determine the influence, if any, of alternate end dates and period lengths (see Appendix F). Since Rutledge (107) noted a persistence factor, allowance was made in the weather analysis program for this likelihood.

During simulation, the first day of a haying season was either 'good' or 'bad', good if the random number was less than or equal to the probability of a good day. Then the period length was chosen from the appropriate weather function (see figures 7 and 8) by another random number. Subsequently, good and bad periods alternated until the forage crop was completely harvested or until the forage cut earliest had sufficient time to regrow and reach the flowering stage. Heinrichs, Troelsen and Warder (59) found the mean interval from cutting to flowering to be 40.7 days, with Rambler and related alfalfa varieties requiring 44.3 days on the average. For this study, a 44-day period was decided on since more accurate growth functions were unavailable. Figure 9 gives the general steps used in this weather subroutine. Provision was made to calculate the potential feeding value of forage left uncut at the end of this 44-day period.

<u>6.1.5 Transport of direct-cut forage</u> -- Maximum payloads for truck and wagon transports were nine and eight tons, respectively. In the analysis, one ton was subtracted from maximum payloads as a weight allowance for a forage box. The eight-ton figure roughly corresponded to the maximum payload observed for different wagon running-gear (see table D1). The

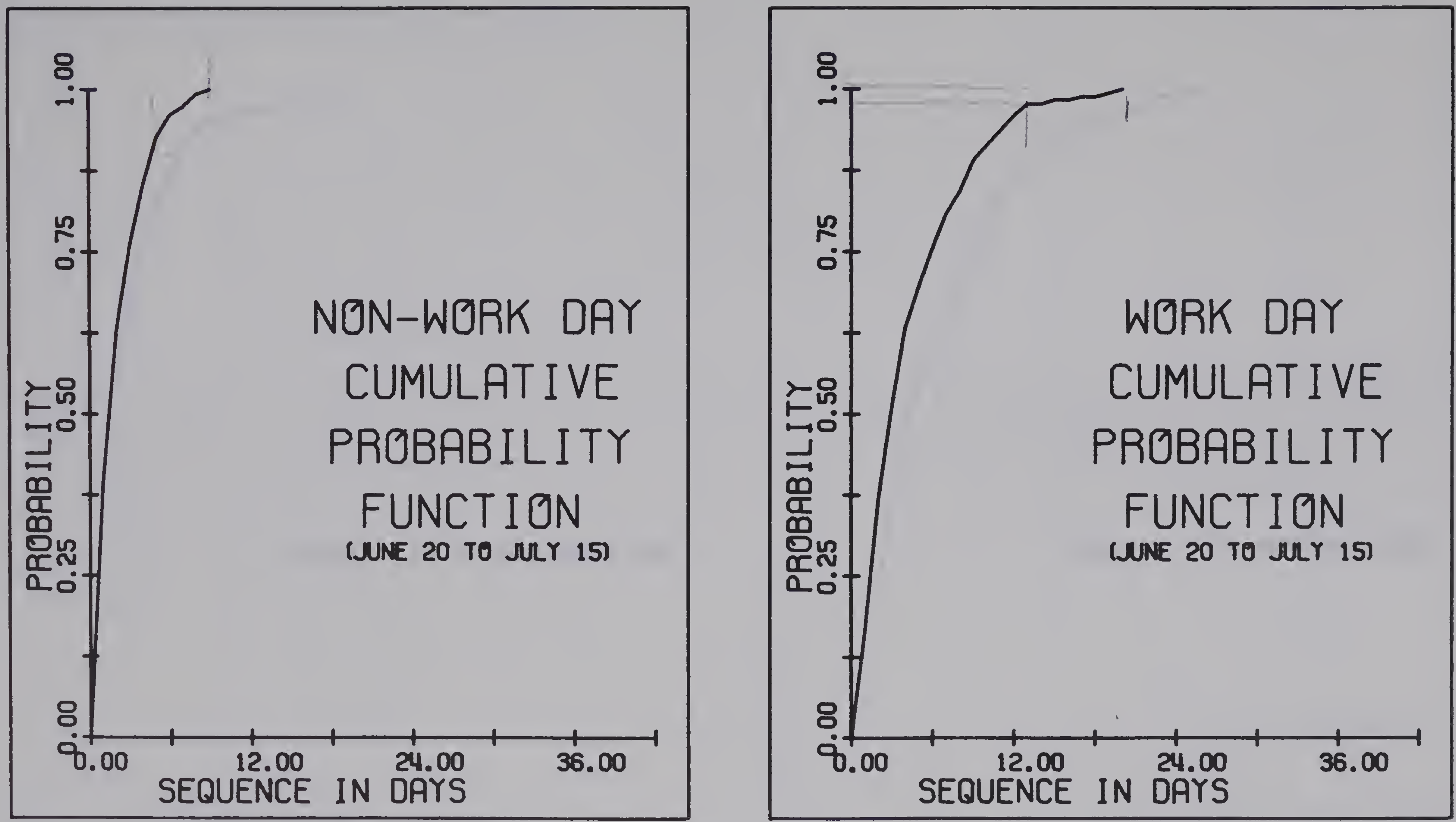


Figure 7. Cumulative forage-cutting probabilities - first cut.

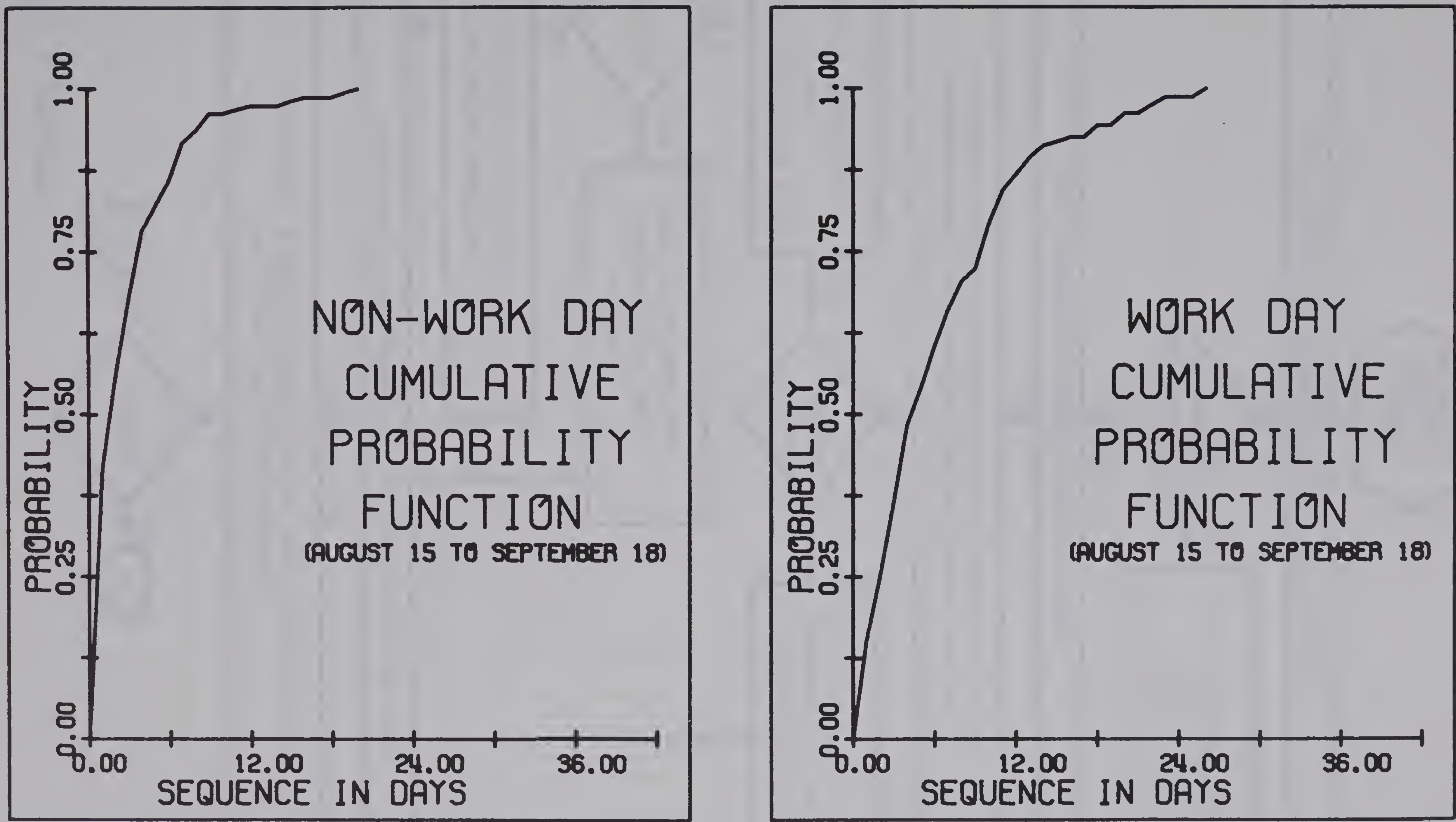


Figure 8. Cumulative forage-cutting probabilities - second cut.

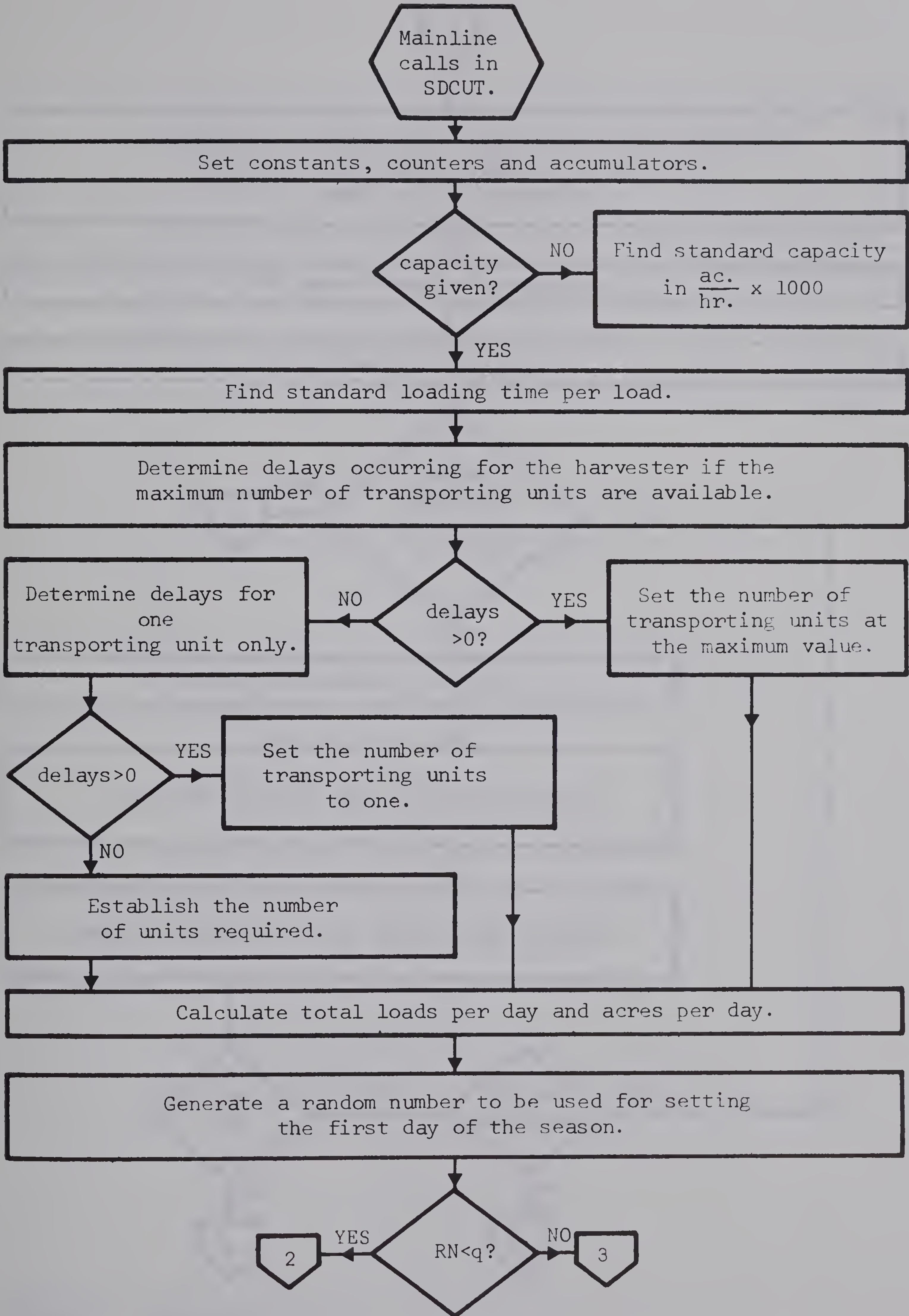


Figure 9. Continued.

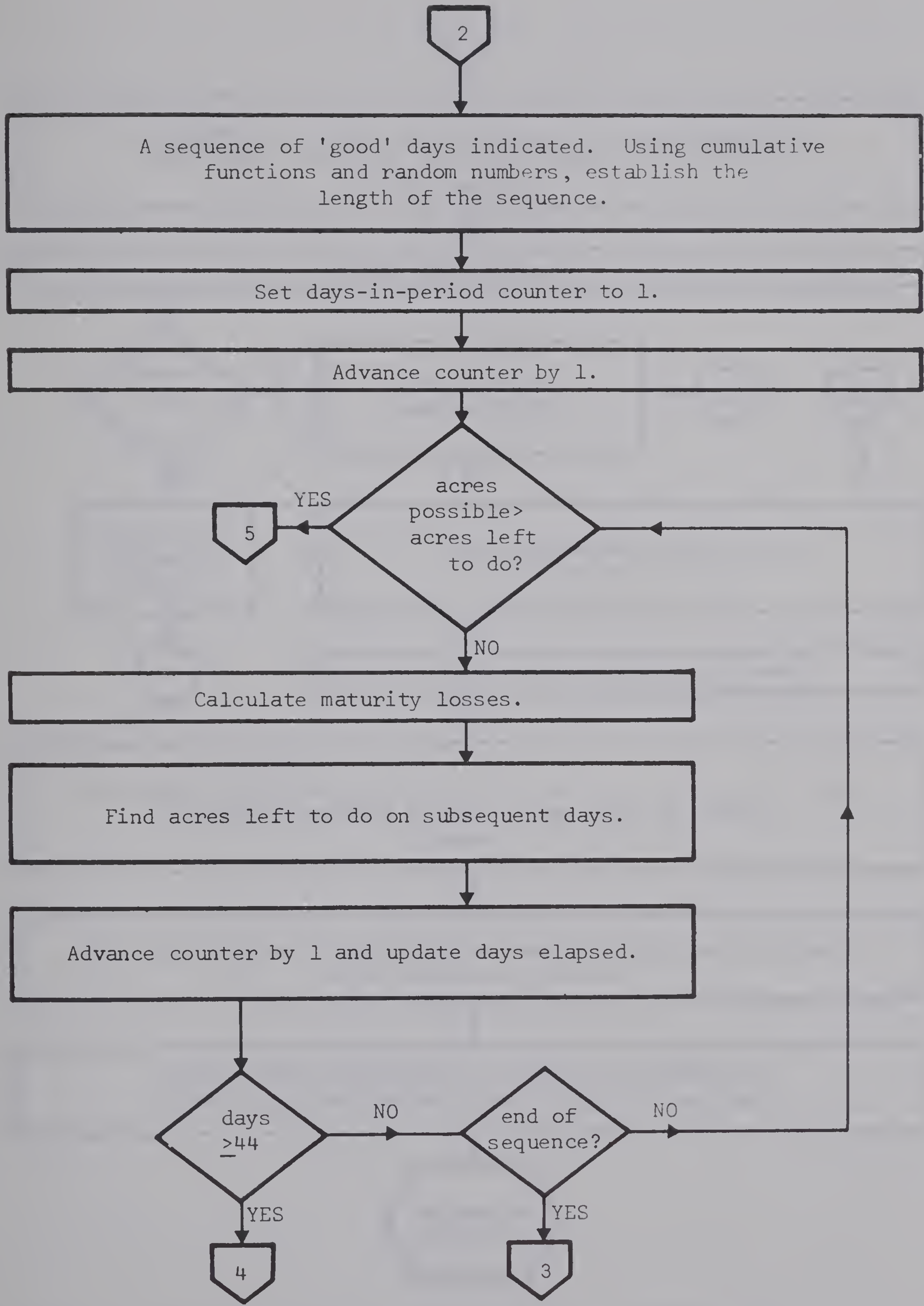


Figure 9. Continued.

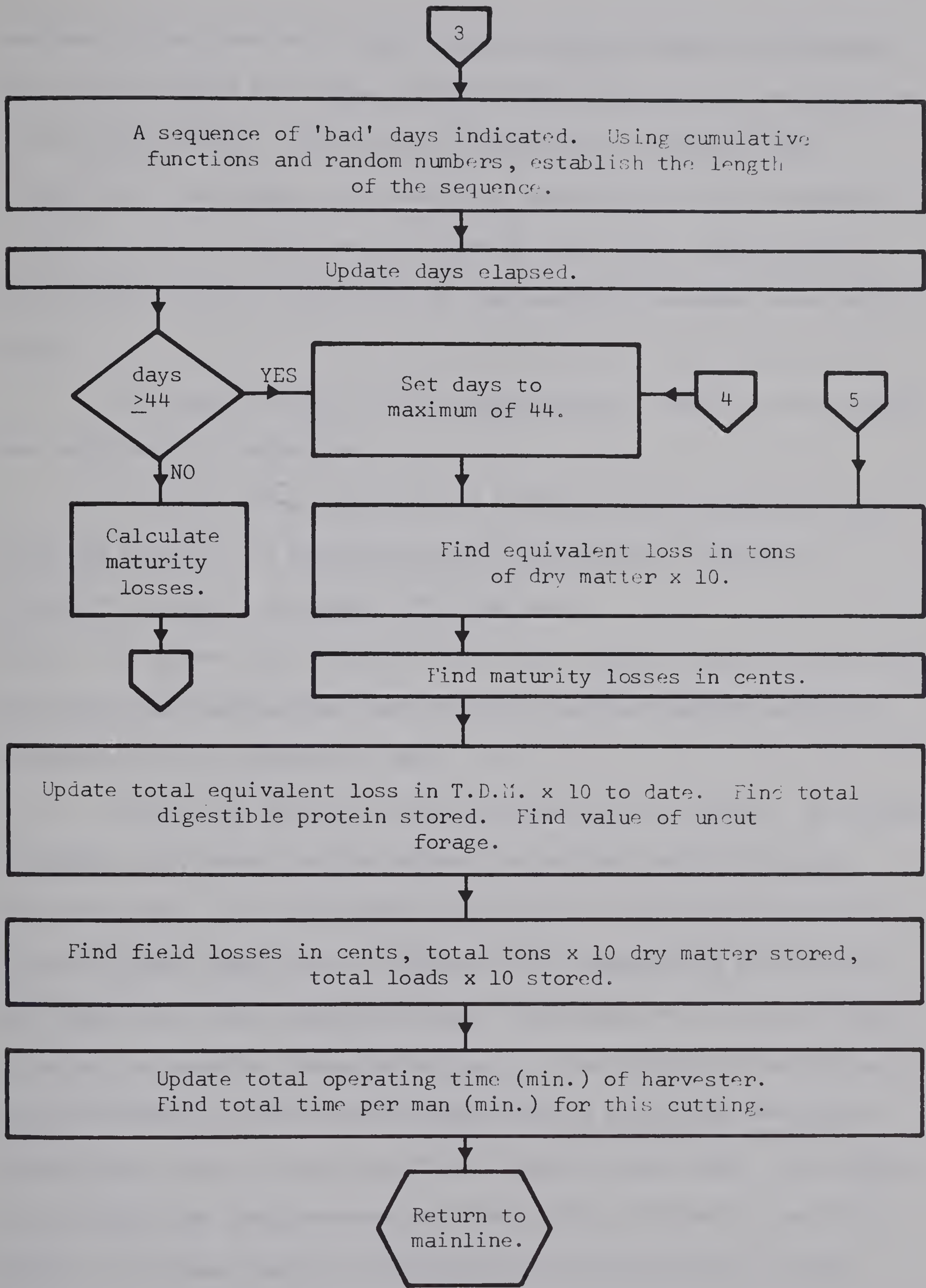


Figure 9. Flow chart of the weather subroutine for direct-cut forage harvesting.

maximum of nine tons for a farm truck was chosen because the side-tip wagon drawn behind the forage harvester had a maximum net load of eight tons of wet material. For any one transaction the maximum gross weights for farm wagons and trucks were selected from their respective ranges of four to eight tons and three to nine tons. Half-ton increments were decided on since this is the capacity increment prevalently used.

Dry matter density for the high-moisture forage on the load was set arbitrarily at eight pcf.

In calculating the number of transport units required to work with one harvester, a step-wise method approximating "Tischler's formula" as used by van Kampen (69) was used.

Note: The several time elements within the transport-cycle (other than road time and loading time) were stored in halfword MATRIX SAVEVALUE 1 *referred to in the program as* MH1.

Dilke (39) observed a hitching time of 2.55 minutes for two men hitching a four-wheel trailer behind a pto-driven forage harvester. For this study, a hitching-unhitching cycle of 5.10 minutes was used since the full wagon must be hitched to the transporting tractor and the empty one to the forage harvester. If trucks were used, the above time was replaced by a dump-cycle time for the hydraulic side-tip wagon of 0.75 minutes. This datum was gained from a spot-check observation made by the author at the farm of Omer Brassard near Leduc. The figure falls within the range observed by Dilke (39) for hydraulic rear-tip wagons. The dump time for trucks was set at 0.61 minutes, the mean time noted by Dilke (39) for hydraulic rear-tip wagons. Keller (70)

reported an unloading time of 6.60 minutes for wagons with an unloading elevator and a grass-clover forage capacity of 2400 kilograms. These figures equate to 2.70 standard minutes per ton, the figure used in this program for self-unloading forage boxes. Manoeuvering time for dump transports was taken from Dilke (39) as 1.81 minutes per load. This time was a composite of elements: approach tipping point (0.43 minutes), open tailboard (0.50 minutes), close tailboard (0.52 minutes), and pull away from tipping position (0.36 minutes).

In all cases, checks were made on other potentially limiting factors such as blower capacities, elevator conveying rates, dehydrator feed and dehydration rates, and silage packing rates before the transport-cycle time was fully calculated.

6.1.6 Dehydrators -- Only one dehydrator was included in this study. The total dehydrator cost included the hydraulic lift apron with a 800 ft^3 holding capacity, the automatic feeder with a discharge rate of 775 to 2325 ft^3/hr, the cyclomatic dehydrator with a maximum fuel oil requirement of 180 gph, the required electric motors to a total of 122 hp, and the necessary concrete pads and supports (see section D3). Component capacities were checked to spot limitations on transport loading rates, if such existed. Although Richey (104) claimed the equilibrium moisture content of alfalfa to be 5% to 8% (wet basis), a dehydrated value of 10% moisture content was used, a figure used by the manufacturer in the specifications and well within the ranges given by Hall (55) for storing alfalfa hay. The manufacturer specified a 18,000 lb/hr evaporative capacity when the initial moisture content was not less than 70%

(wet basis). An efficiency factor of 50% to 85% was used for the rotary drum drier, as mentioned by Fortin (20).

Weather protection for the dehydrator complex consisted of a pole-frame, truss rafter, open building. Constructed cost for such a building in the Edmonton area can range from $0.95 to $1.40 per square foot depending on the dimensions and on the roofing material. For any particular transaction, the cost figure was selected randomly from this range.

The forage was conveyed from dehydrator to storage via a chain-and-flight farm elevator. Because the building arrangement is not established, because the vertical lift depends on the position of the dehydrator outlet and on the maximum height of stored product, and because these farm elevators differ in flight dimensions, the required length of conveyor was arbitrarily set equal to the length of the storage facility plus 10 feet. Angle of repose was set at 60 degrees (a figure used by Neubauer and Walker (93) for chopped hay); conveyor speed was set at 125 fpm (suggested as maximum by the Materials Handling Manual (24)); flight dimensions of one conveyor were used, 3 inches deep by 21 inches wide with a 14-inch separation. Even at a normal flight volume of level full, the elevator capacity was found to be adequate for handling the dehydrated alfalfa at up to 100% dehydrator efficiency, i.e., 6.6 tons per hour at a low density of four pcf.

The storage building chosen had the common 32-foot width with a 16-foot sidewall. The building was of pole-frame construction with truss rafters, totally enclosed and built complete with concrete floor.

If filled to a depth of 14 feet, the effective endwall area was 448 ft^2. At a bulk density of 10 pcf, capacity could be calculated at roughly 2.24 tons of material per linear foot. Constructed cost of the building was calculated on a square foot basis at from $1.25 to $1.50 per square foot plus $0.60 per square foot of concrete.

The unloading method chosen utilized a tractor scoop. The largest front-end scoop size available in Edmonton for an agricultural tractor was 21 ft^3. The low density of material meant that a larger unit would be preferable as well as feasible. No time data on this method of unloading chopped hay were available. The horizontal-silo unloading capacity of a tractor-mounted manure bucket was chosen as a guideline (discussed in section 6.1.7). The alfalfa hay was loaded at the same rate in tons per hour as the alfalfa silage, times the volume ratio (see Appendix G). Little time data seemed to be available for <u>any</u> method of unloading and transporting chopped forage.

<u>6.1.7 Pit silos</u> -- Although a particular farmer's choice of horizontal silo depends largely on the terrain next to the feeding site, this more general analysis considered only the pit silo, cheaper to construct than a bunker silo if a sidehill is available.

Design capacity was based on a constant density of 35 pounds per cubic foot of silage, as suggested in the Materials Handling Manual (124). Although Richey (104) claimed that well-packed silage could have a 40 pcf density, use of the lower figure tended to ensure sufficient capacity for the crop to be stored. Because of the limits of this study, the alternative silo sizes were not programmed to make sure that a minimum of four inches per day of feeding face is fed to avoid possible spoilage (124). Physical load-bearing characteristics

of the soil are another factor that alter the structural requirements of the storage facility. For this particular analysis, a sidewall slope of 1 : 3 was used, as suggested by Neubauer and Walker (93), excavation extended three feet beyond the inside silo width at ground level. Excavation was custom done and was priced on a loose-soil basis. Floor costs were based on a six-inch concrete slab one foot wider than the inside base width plus wire mesh; wall costs were based on a four-inch concrete wall reinforced with $\frac{1}{2}$" Re-bar 12" on centre in both directions. Both costs and capacities were calculated per linear foot, the required length of silo calculated in the program from the tons of material to be stored. Figure 10 gives the inside dimensions and indicates the effective volume of virgin soil to be excavated. Excavation costs exclude any trucking costs for soil that must be transported away from the excavation site. Given costs of

excavation	at	40¢/yd^3 for loose soil
concrete	at	\$18/yd^3 delivered
6" x 6" 10/10 mesh	at	\$45/1000 ft^2
6 mil polythene	at	\$17.50/1000 ft^2 and
$\frac{1}{2}$" Re-bar	at	\$8.10/100 ft,

the following cost equations were used as part of a small computer program:

$$\text{Excavation cost } \frac{\$}{\text{ft}} = (w + \frac{2h}{3} + 3\text{ ft})(h\text{ ft})(\frac{1\text{ yd}^3}{27\text{ ft}^3})(\frac{\$0.40}{\text{yd}^3})(\frac{15\text{ yd}^3}{10\text{ yd}^3})$$

$$\text{Floor material cost } \frac{\$}{\text{ft}} = (W + 1\text{ ft})(\frac{\$45}{1000\text{ ft}^2})(\frac{6\text{ in}}{12\text{ in/ft}})(\frac{1\text{ yd}^3}{27\text{ ft}^3})(\frac{\$18}{\text{yd}^3})$$

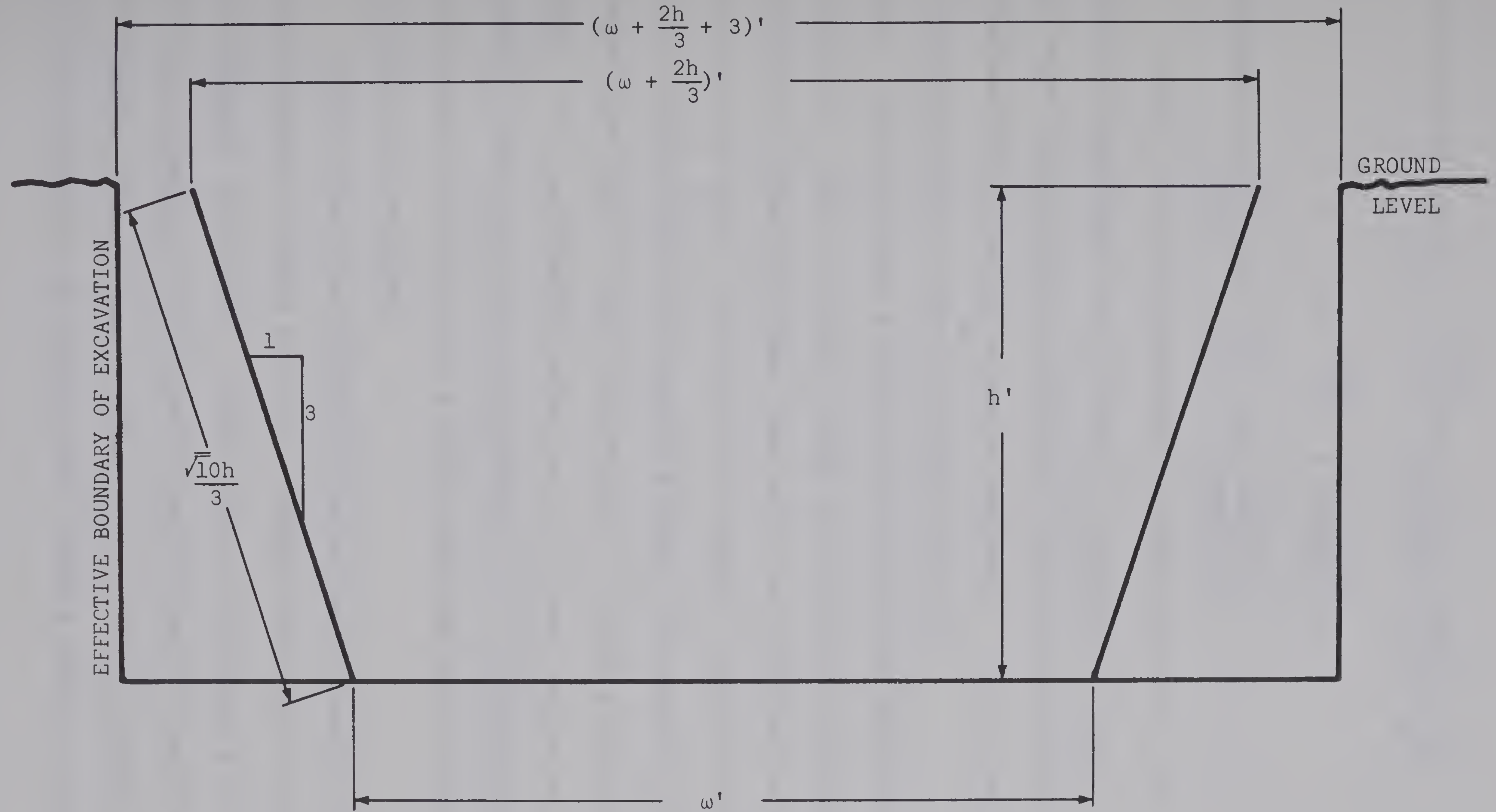


Figure 10. Pit silo dimensions.

$$\text{Wall material cost } \frac{\$}{\text{ft}} = 2\left(\frac{\sqrt{10h}}{3}\ \text{ft}\right)\left(\frac{4\ \text{in}}{12\ \text{in/ft}}\right)\left(\frac{1\ \text{yd}^3}{27\ \text{ft}^3}\right)\left(\frac{\$18}{\text{yd}^3}\right)$$

$$+ \left(\frac{2\sqrt{10h}}{3} + 1\ \frac{\text{ft}}{\text{ft}}\right)\left(\frac{\$8.10}{100\ \text{ft}}\right)$$

$$\text{Polythene cost } \frac{\$}{\text{ft}} = \left(w + \frac{2h}{3} + 3\ \text{ft}\right)\left(\frac{\$17.50}{1000\ \text{ft}^2}\right)$$

Labour costs were approximated as 50% of material costs. The silo was depreciated over 20 years on a straight-line basis. A 1.2% per annum repair charge was added, the figure used by Alberta Department of Agriculture extension engineers. The polythene cost is a yearly one since it must be replaced every year.

Note: Table 9 includes the input data listed under FUNCTION 28 *through* FUNCTION 31. *The silo chosen during any particular transaction was selected at random from these sizes with some qualifications as to which ones could be chosen. Silo width, for example, depended on whether one or two tractors were to be used for packing. The method of silage removal from the silo also had something to do with permitted silo depths. If a self-feeding method was to be used, only silos with a maximum depth of six feet were permitted. If a tractor-mounted unloader was selected, only silos with a depth within the upper reach of the unloader were considered.*

Packing rates, like dehydration rates, had a potential influence on the maximum unloading time for a transport unit, and consequently on the transport cycle itself. Within limits, time required for packing can vary depending on the manager's specifications to operators and on the rapidity of unloading. In other words, if loads arriving at the silo put pressure on the packing units, packing time per load may be

TABLE 9. INPUT DATA FOR PIT SILOS

Dimensions h' x w' (ft)	Nearest ft^3 per linear ft	Initial Cost ($/ft)	Polythene Cost (¢/ft)	Dimensions h' x w' (ft)	Nearest ft^3 per linear ft	Initial Cost ($/ft)	Polythene Cost (¢/ft)
6 x 12	84	17.20	23	13 x 26	394	42.00	45
6 x 15	102	19.30	26	13 x 30	446	45.42	50
6 x 20	132	22.81	32	13 x 35	511	49.71	56
6 x 25	162	26.31	38	13 x 40	576	53.99	62
6 x 30	192	29.82	44	13 x 45	641	58.27	68
6 x 35	222	33.32	50	15 x 30	525	50.15	52
6 x 40	252	36.82	56	15 x 35	600	54.66	58
8 x 16	149	23.69	29	15 x 40	675	59.16	64
8 x 20	181	26.68	34	15 x 45	750	63.66	70
8 x 25	221	30.40	40	15 x 50	825	68.17	76
8 x 30	261	34.13	46	20 x 40	933	72.61	68
8 x 35	301	37.85	52	20 x 45	1033	77.66	74
8 x 40	341	41.58	58	20 x 50	1133	82.72	80
10 x 20	233	30.66	36	20 x 55	1233	87.78	86
10 x 25	283	34.61	42	25 x 50	1458	98.02	84
10 x 30	333	38.56	48	25 x 55	1583	103.64	90
10 x 35	383	42.51	54	25 x 60	1708	109.25	96
10 x 40	433	46.46	60	25 x 65	1833	114.87	102

dropped. In the absence of more accurate information the figures used by Beauvois et al. (10) were employed. Tests were conducted in the program to ensure constant packing time even at the expense of delaying the transporting cycle. Use of a toothed implement on these packing tractors was not incorporated as an alternative, but improved packing would likely occur with little if any change in packing time per ton (39).

Self-feeder data was difficult to come by, probably because of the great diversity in methods, design and management. Cost of the self-feeder and time for moving it were assumed (see Appendix G). An exception was made in extending the analysis somewhat beyond the bounds of the study specified in section 3.1. Trampling losses in self-feeding high-moisture silage were included in evaluating alternative methods. Richey (104) claimed one might expect up to a 50% dry matter loss. With good management practices, this figure could perhaps be reduced to 25%. In this program, a range of 25% to 50% was used, the actual value chosen randomly.

Unloading capacities for the tractor-mounted manure bucket and the horizontal-silo unloader were given ranges of seven to eight tons and 12 to 15 tons of wet material per hour respectively. The only source that the author could find, other than specification sheets, that referred to such unloading rates was The Grain Grower (121).

6.2 Optimum Systems

Forage systems requiring no field curing were simulated at both the 200- and the 300-acre levels with a computer time limit of 30 minutes each. For each pass through the network, one system and one year of

weather were simulated. These simulated systems were grouped according to the field machinery used and then ranked within each group in ascending order of cost per ton of digestible protein fed. This cost figure is the proportionate amount of the total cost that can be attributed to the protein in the forage, given the content of protein and energy in the fed material and the cost of each as outlined in section 5.2. Subsequently, the groups were ranked in ascending order of their least cost entry in $/T DP fed. Note that not all systems within each group were necessarily identical because of probable differences in storage methods and in the levels of certain variables. Although insufficient passes could be made in 30 minutes to define a specific system as optimal, the number of years of weather simulated for any one field harvesting method usually permitted a rough assessment of alternative systems, if not a statistically reliable one.

At the 200-acre level, 857 passes were made through the network; at the 300-acre level 792 passes were completed. Using the equation in section 4.2, the probabilities of selecting the least likely route ($p = 0.0052$) at least once were 0.989 and 0.984 for 200 and 300 acres respectively. The probabilities of at least three selections of this route dropped below 0.8. In other words, more years of weather would be needed to be reasonably sure of pinpointing the optimum system. Upon grouping systems as previously described, the probabilities of selecting the least likely group ($p = 0.0156$) at least six times became 0.992 and 0.985. For ranking, the array size was limited throughout to the first 800 entries. Only the first 200 of the ranked passes were graphed - a compromise between number of systems and plot definition.

Tables 10 and 11 indicate the field machinery used in each of the ranked groups of passes (essentially different systems), the system

TABLE 10. FORAGE MACHINERY SYSTEMS GRAPHED FOR 200 ACRES - DIRECT-CUT HARVESTING[a]

Machinery System Number(s)	End Product		Forage Harvester				Transport Source		Transport Type				Tractors Packing Silage (Number)
	HM SLG	DEHY	PT FL	PT CYL	PT FLY	SP	OWNED	HIRED	SUW	DPW	PBT	DPT	
1-14	x			x				x			x		1
15-23	x			x				x				x	1
24-28	x				x			x			x		1
29-35	x				x			x	x				2
36-43	x		x					x		x			1
44-52	x		x					x		x			2
53-61	x			x				x				x	2
62-70	x				x			x			x		2
71-74	x				x			x		x			1
75-81	x			x				x			x		2
82-90	x				x			x				x	1
91-97	x		x					x				x	2
98-106	x				x			x	x				1
107-112	x				x			x		x			2
113-119	x		x					x			x		2
120-129	x				x			x				x	2
130-135	x		x					x			x		1
136-142	x			x				x	x				2
143-147	x		x					x				x	1
148-150	x			x				x		x			2
151-155	x			x				x		x			1
156-160	x					x		x	x				1

TABLE 10. (continued)

Machinery System Number(s)	End Product		Forage Harvester				Transport Source		Transport Type				Tractors Packing Silage (Number)
	HM SLG	DEHY	PT FL	PT CYL	PT FLY	SP	OWNED	HIRED	SUW	DPW	PBT	DPT	
161-165	x		x					x	x				1
166-175	x		x				x			x			1
176-180	x		x				x		x				2
181-187	x					x		x	x				2
188-194	x					x		x				x	2
195-199	x					x		x		x			1
200-207	x			x			x			x			2

[a] LEGEND:

HM SLG - high moisture silage
DEHY - dehydrated forage
PT FL - pull-type, flail-type
PT CYL - pull-type with cylinder-type cutterhead plus cutterbar
PT FLY - pull-type with flywheel-type cutterhead plus cutterbar
SP - self-propelled with cutterbar
SUW - self-unloading wagon
DPW - dump wagon
PBT - power-box truck
DPT - dump truck

TABLE 11. FORAGE MACHINERY SYSTEMS GRAPHED FOR 300 ACRES - DIRECT-CUT HARVESTING[a]

Machinery System Number(s)	End Product		Forage Harvester				Transport Source		Transport Type				Tractors Packing Silage (Number)
	HM SLG	DEHY	PT FL	PT CYL	PT FLY	SP	OWNED	HIRED	SUW	DPW	PBT	DPT	
1-14	x			x				x			x		1
15-19	x				x			x			x		1
20-27	x			x				x				x	2
28-35	x			x				x				x	1
36-44	x				x			x			x		2
45-51	x			x				x			x		2
52-58	x				x			x	x				2
59-67	x				x			x				x	1
68-71	x				x			x		x			1
72-80	x		x					x		x			2
81-90	x				x			x				x	2
91-98	x		x					x		x			1
99-107	x				x			x	x				1
108-114	x		x					x			x		2
115-120	x				x			x		x			2
121-126	x		x					x			x		1
127-130	x		x					x				x	1
131-135	x					x		x					1
136-142	x		x					x				x	2
143-147	x			x				x		x			1
148-154	x					x		x				x	2
155-161	x					x		x	x				2

TABLE 11. (continued)

Machinery System Number(s)	End Product		Forage Harvester				Transport Source		Transport Type				Tractors Packing Silage (Number)
	HM SLG	DEHY	PT FL	PT CYL	PT FLY	SP	OWNED	HIRED	SUW	DPW	PBT	DPT	
162-166	x					x		x		x			1
167-171	x					x		x				x	1
172-176	x			x			x		x				2
177-179	x					x		x			x		1
180-186	x			x				x	x				2
187-189	x			x				x		x			2
190-196	x					x		x			x		2
197-206	x		x				x			x			1

[a] See table 10 for legend.

number corresponding to its position in the ranked groups. These numbers are identical to those used on the X-axes of figures 11 to 20. As expected, the least-cost systems utilized high-moisture silage. The high fixed cost of dehydrators priced such systems out of the silage class, even at the 300-acre level. Self-propelled forage harvesters proved sub-optimal to pull-type harvesters, again likely due to high annual fixed costs. Hiring appeared preferable to owning transport units, the type of unit having little influence on the optimality of the systems. However, the likelihood of a favorable bias towards custom transporting (provided such is available on demand) has already been mentioned (see section 5.3). Where transport units were purchased, wagons were selected first. This pattern may be traced to the charging of all transport fixed costs to the forage system, whereas farmers owning such units generally find additional uses for them, thus reducing the yearly charge to the forage operation. For 200 acres, the type of tractor-drawn forage harvester did not have much influence on the overall system costs, but the flail-type unit did become less favorable at 300 acres.

In figure 11, forage system costs are plotted for the first 200 of the ranked direct-cut systems with acreage set at 200 acres. These yearly costs are expressed as dollars per acre of land in forage. Since the entire acreage was harvested twice for each year of weather simulated, total forage costs per acre harvested would be approximately half of those shown. Note that the total cost per acre includes all fixed, variable and penalty costs incurred as the forage moved from field to exit from storage. Penalty costs alone, though not always an out-of-pocket expense to the farmer, accounted for 20% or more of the total.

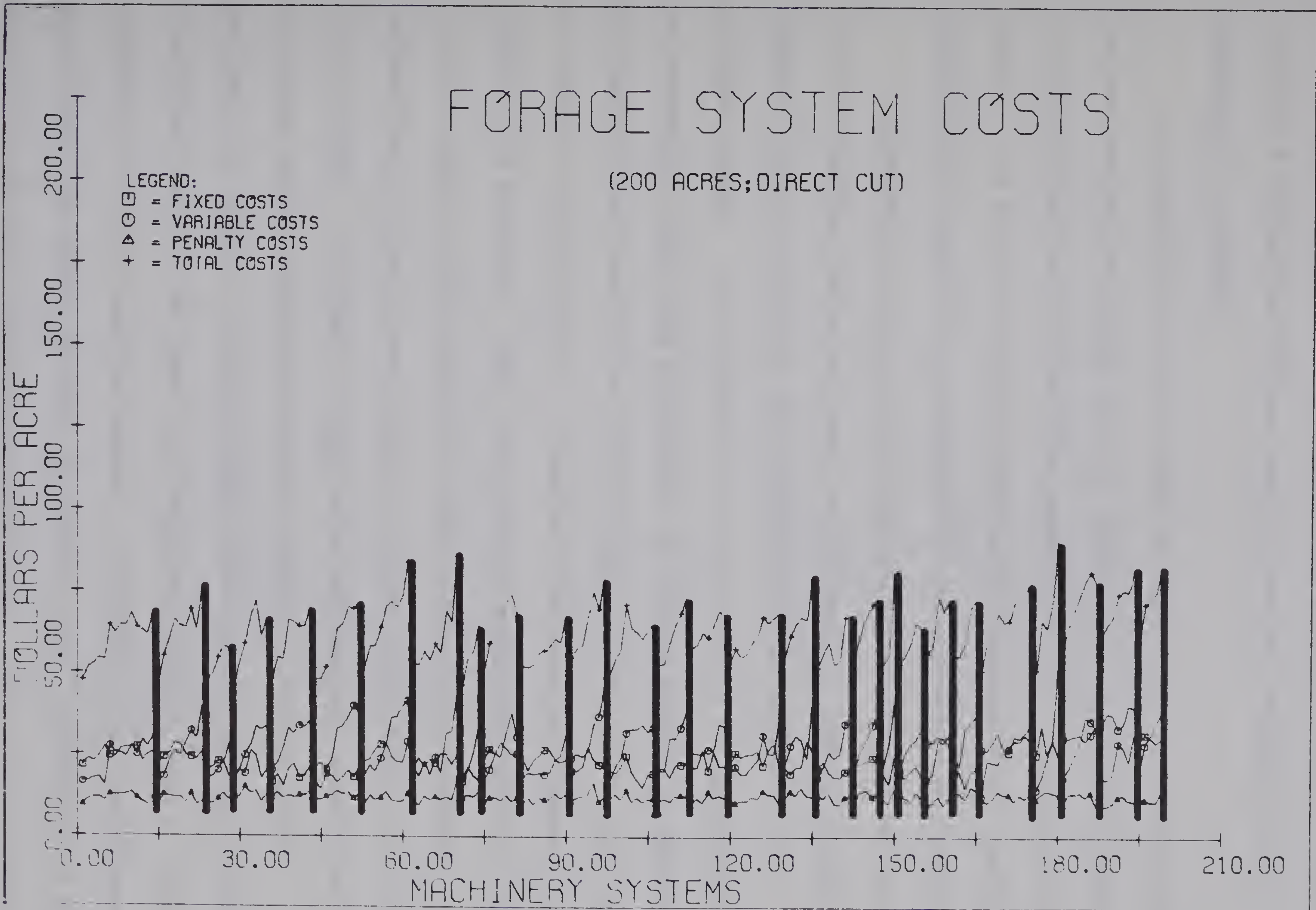


Figure 11. Forage system costs for 200 acres -- direct-cut harvesting.

Figure 12 shows that, for the 200 systems graphed, the entire 200 acres were harvested within the 44-day period for each cutting. Duration of the harvest did not seem to have much bearing on the optimality of a system.

A comparison of the top lines in figures 11 and 13 shows that the cost per acre of forage does not always move in the same direction as does cost per ton of digestible protein fed (note the group of systems numbered 1 to 14), which again underlines the necessity of carefully specifying the criterion for determining the optimality of a system.

Apparently, cost per ton of digestible protein fed and cost per ton of dry matter fed serve almost equally well in ranking systems. Figures 13 and 14 attest to this possibility (see Appendix K for pertinent tables). The variability in cost per ton of digestible protein fed ostensibly arose from differences in storage aspects of the systems. The peaks in the curve do not likely relate to fixed costs (see figure 11) because only one type of storage unit was used for high-moisture silage - the pit-silo. Thus, the unloading method had critical impact on system costs - self-feeding fell below mechanical unloading in desirability in almost every group of systems (check table K1 for the list of nodes). In figure 13, <u>all</u> costs were charged to the protein. If soybean meal is similarly treated, digestible protein can be purchased for \$260/T. Since the graph shows optimal systems incurred even higher costs by the time the forage left storage, some of the cost parameters or levels used are suspect. In figure 14, an approximate mean of \$20/T DM stored (or \$6/T WM stored) looks reasonable, but the cost in \$/T DM fed is again inordinately high. Part of this high cost may have resulted from unrealistic interest and depreciation rates. The

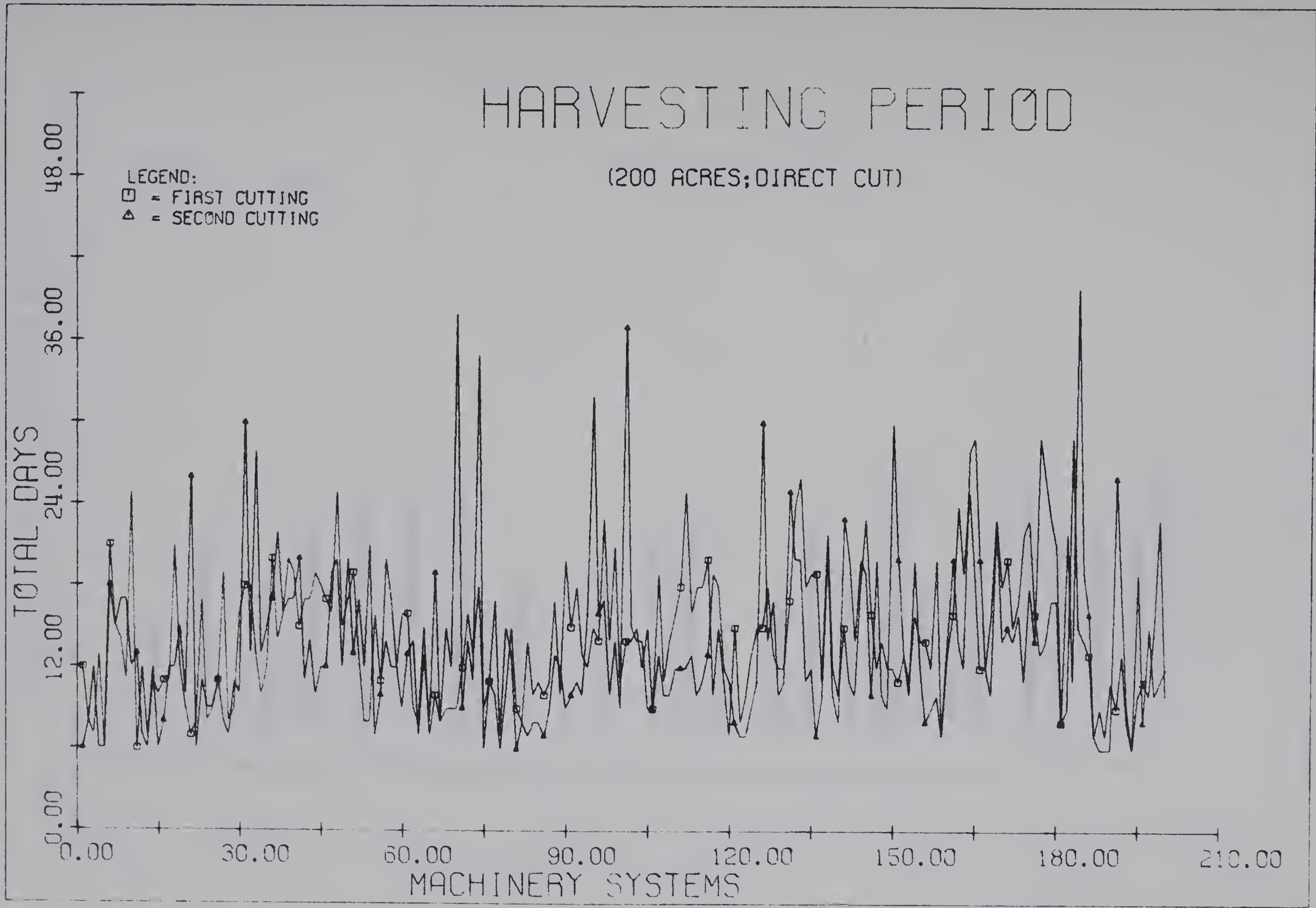


Figure 12. Duration of harvest for 200 acres -- direct-cut harvesting.

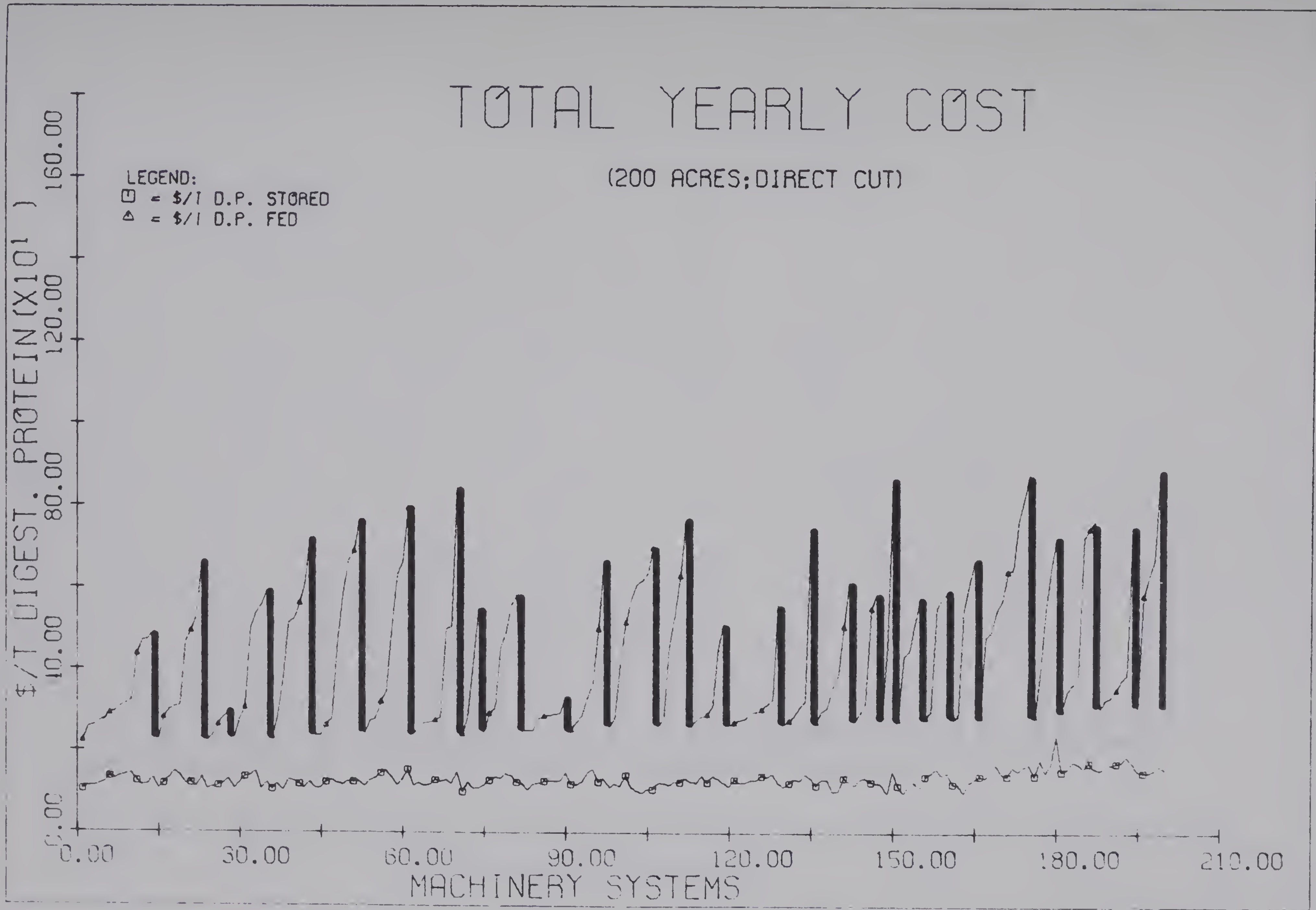


Figure 13. Cost per ton of digestible protein from 200 acres -- direct-cut harvesting.

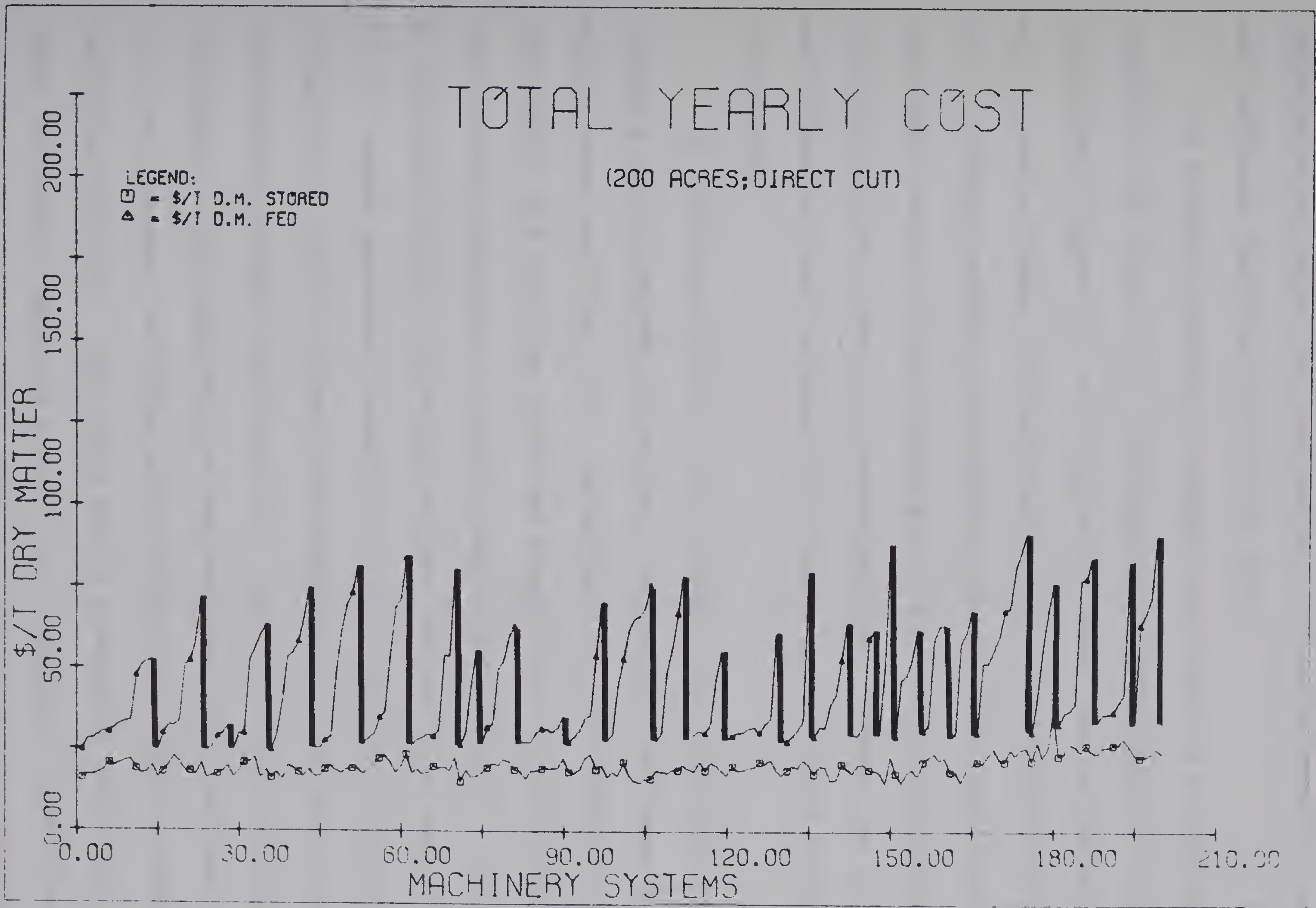


Figure 14. Cost per ton of dry matter from 200 acres -- direct-cut harvesting.

bias against self-feeding of high-moisture silage, introduced as a reduction in dry matter fed (see section 6.1.7 and Appendix G), caused some additional distortion of the cost curves.

As already pointed out, penalty costs comprised a significant fraction of the total cost. The components of this penalty cost are delineated in figure 15. As in figure 11, these costs are shown per acre of land in forage. Storage losses accounted for about half of the total. Although maturity and weathering losses varied considerably, the approximate penalty of four dollars per acre in forage, or two dollars per acre harvested, was not an overwhelming one. Because the crop never had a chance of being weathered, this penalty is solely due to maturity of the crop.

At the 300-acre level, little change in per acre costs occurred for optimum groups of systems, other than a narrowing of the range of variation within groups (see figure 16). Harvesting the larger acreage obviously took longer, and this time period was somewhat more variable because of the increased likelihood of weather changes (see figure 17). Cost per ton of digestible protein (figure 18) and cost per ton of dry matter (figure 19) did not change appreciably except for a small reduction in deviations. As expected, penalty costs per acre changed only in the cost of maturity and weathering losses (see figure 20). Due to the direct-cut nature of harvesting, field losses per acre remained essentially the same. Note that on a few occasions, the 44-day period proved insufficient to complete harvesting operations. The losses due to unharvested acres appear on this graph, but did not appear as a cost in the ranking of alternative systems. Generally, the penalty costs could be ranked in ascending order as unharvested acreage penalties, field loss penalties, maturity and weathering loss penalties, and storage loss penalties.

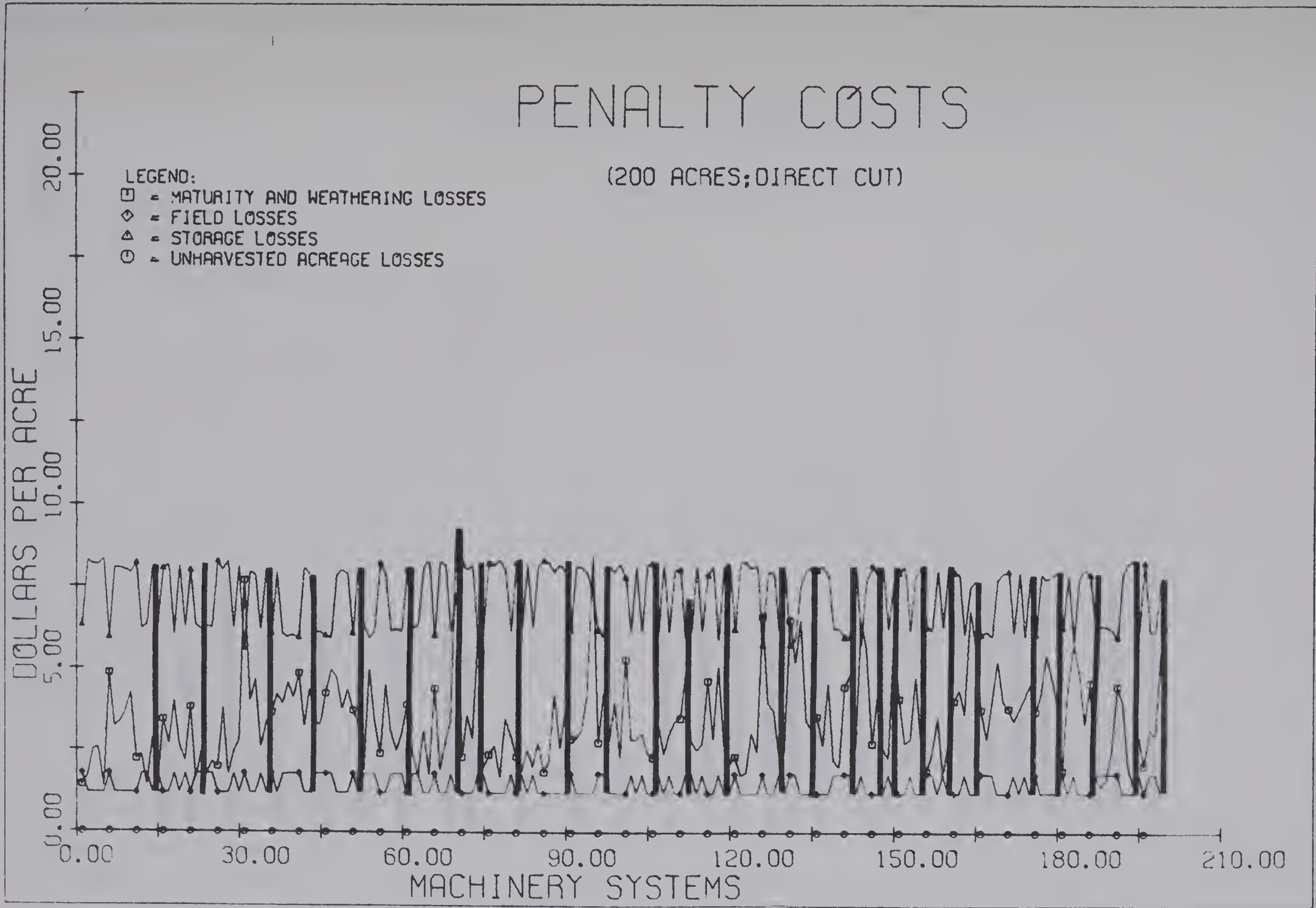


Figure 15. Penalty costs per acre for 200 acres -- direct-cut harvesting.

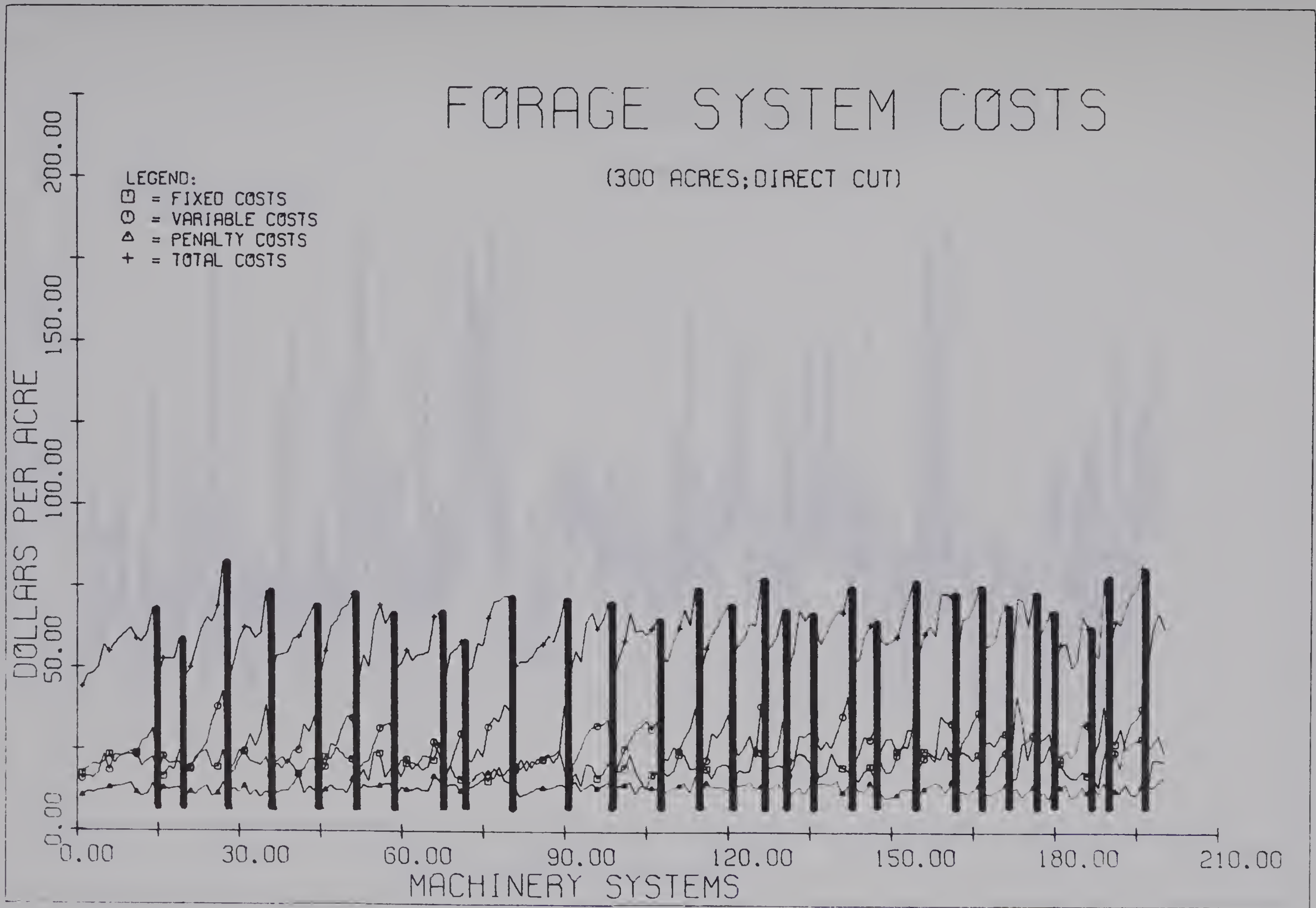


Figure 16. Forage system costs for 300 acres -- direct-cut harvesting.

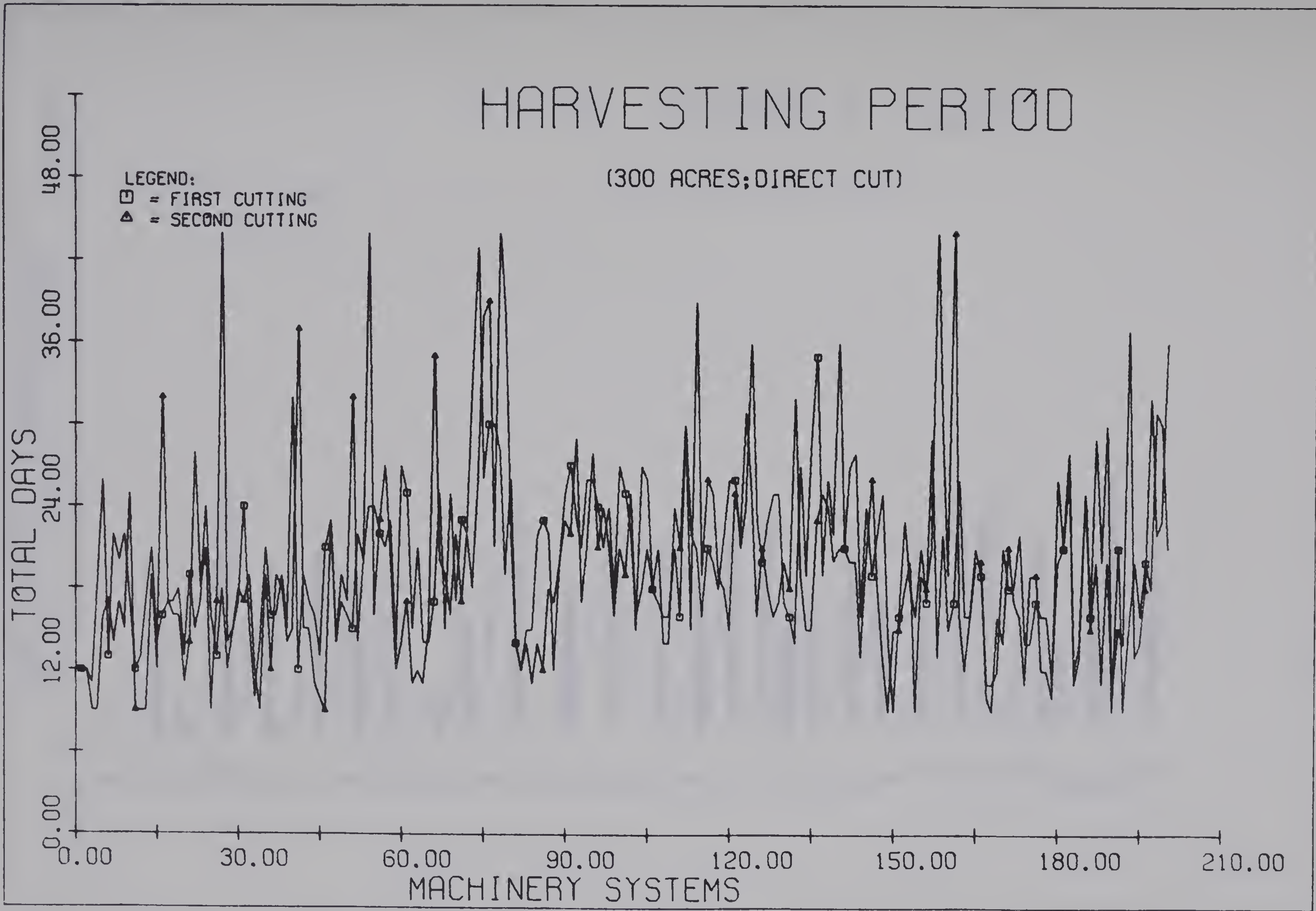


Figure 17. Duration of harvest for 300 acres -- direct-cut harvesting.

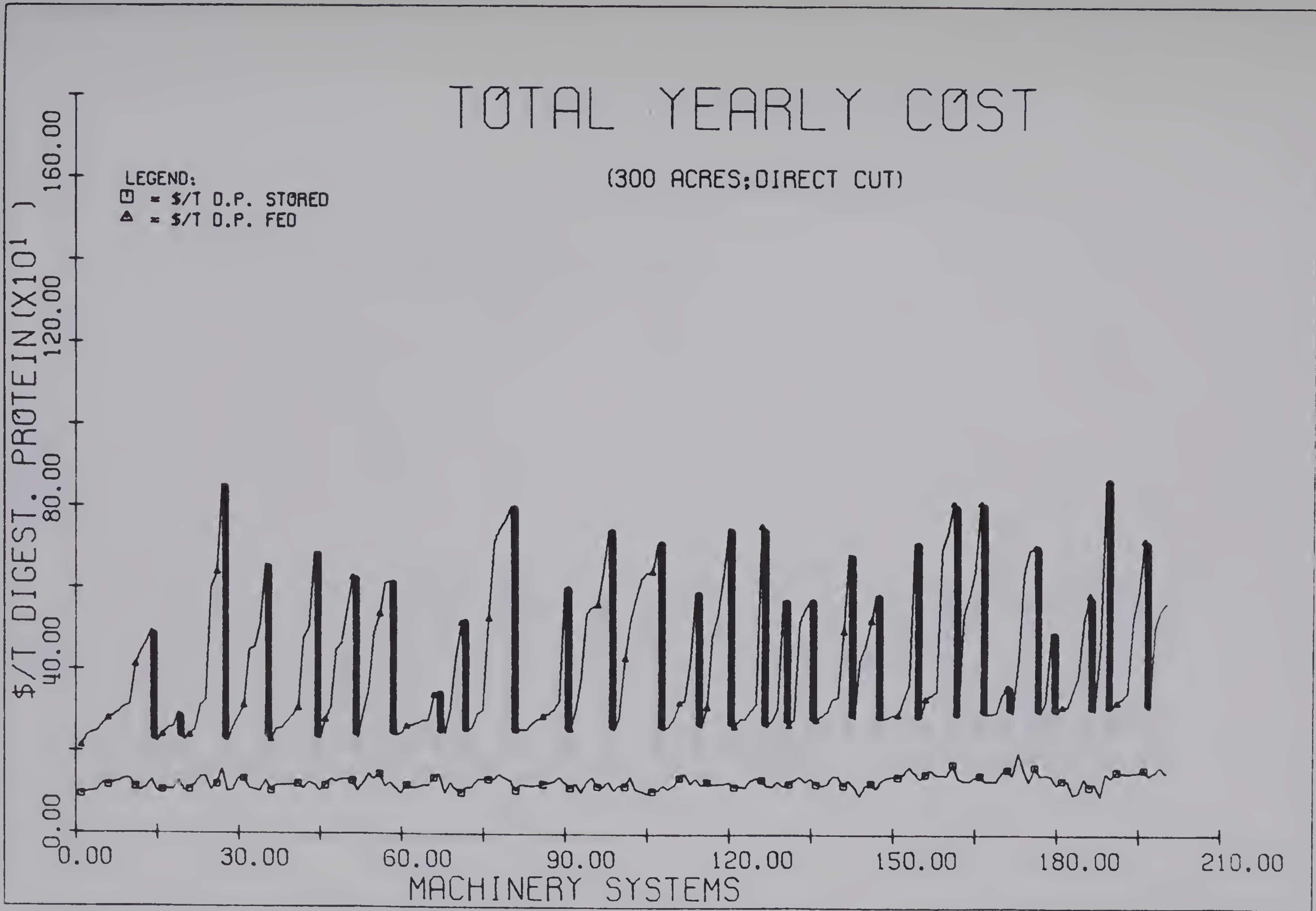


Figure 18. Cost per ton of digestible protein from 300 acres -- direct cut harvesting.

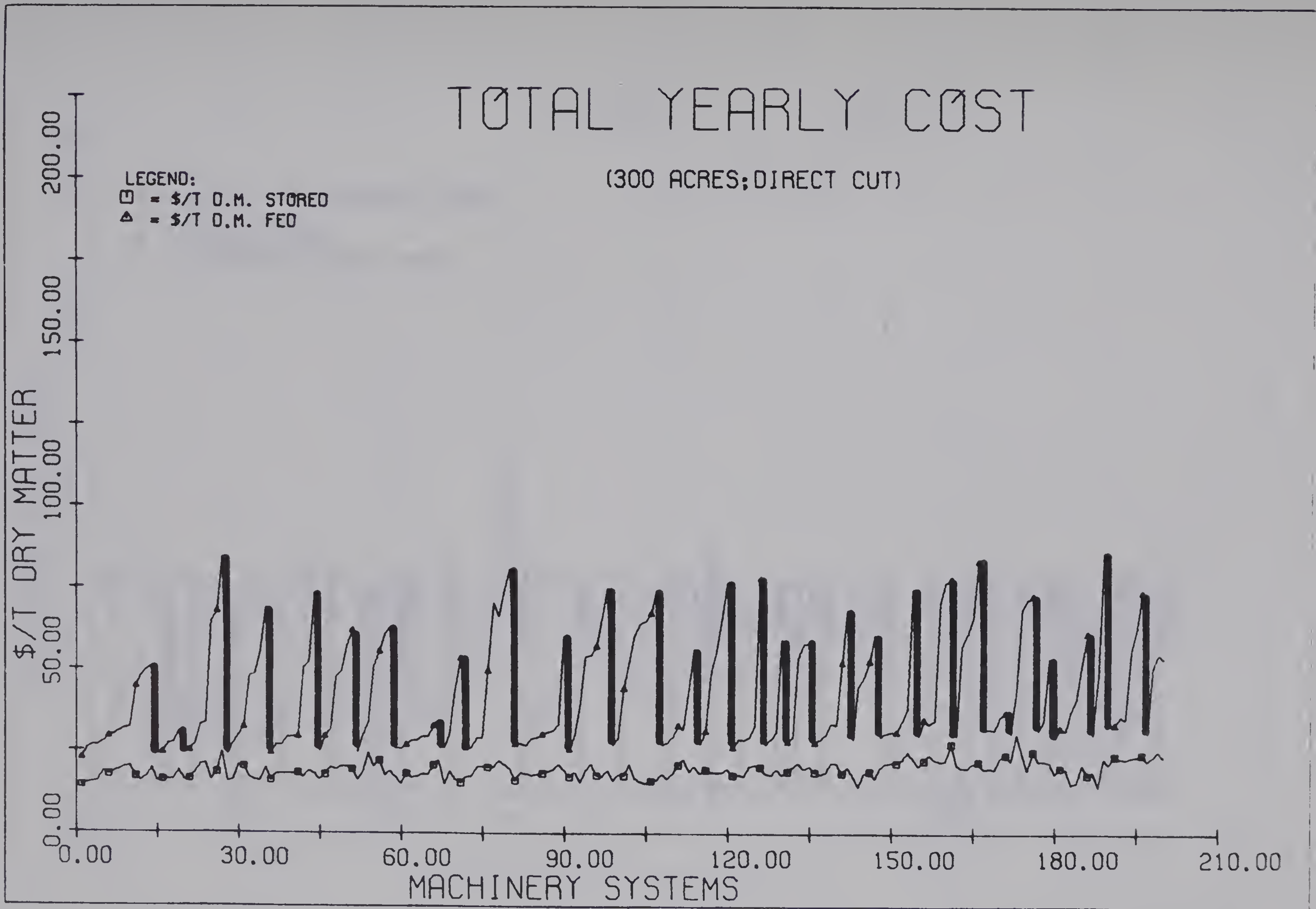


Figure 19. Cost per ton of dry matter from 300 acres -- direct-cut harvesting.

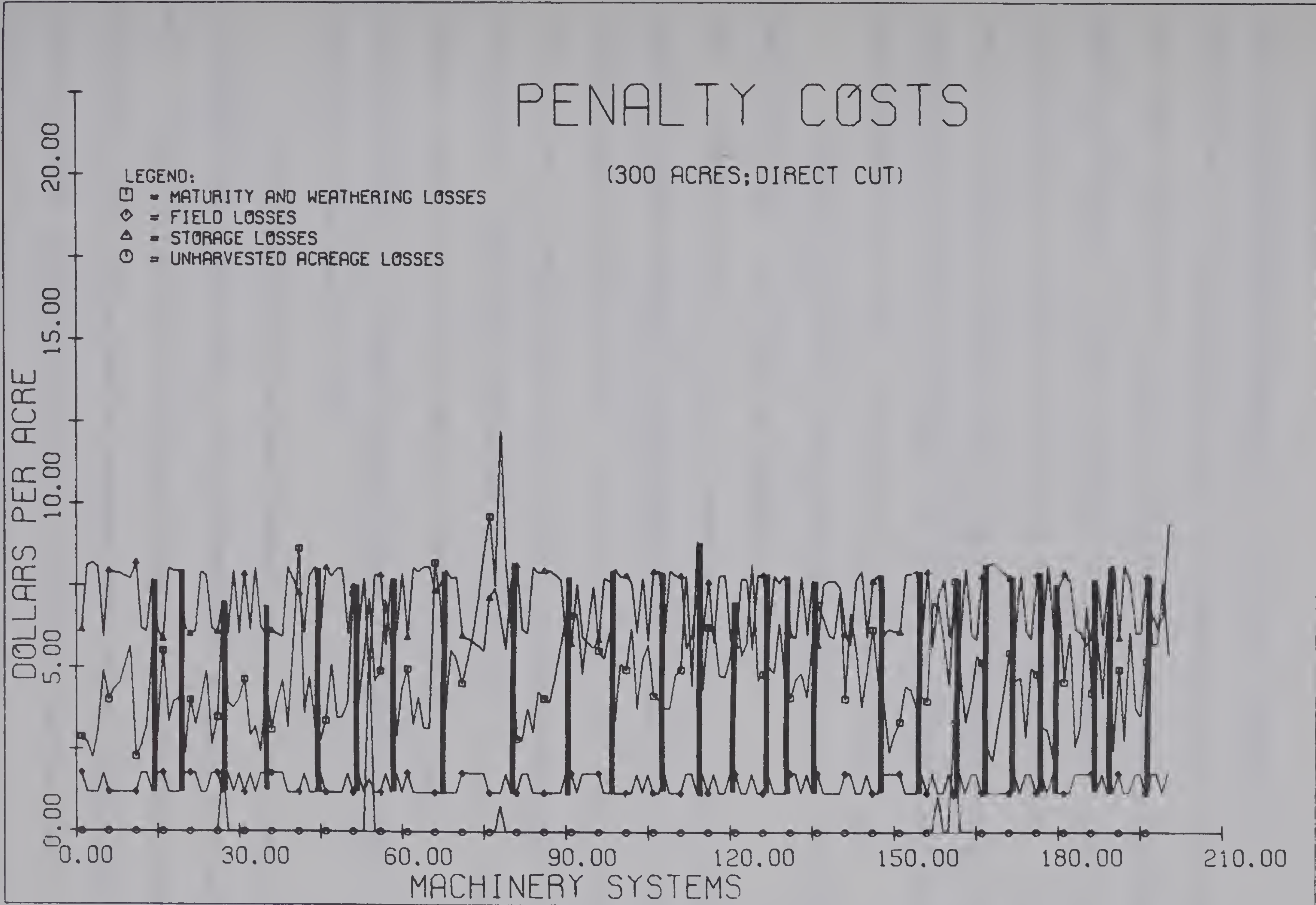


Figure 20. Penalty costs per acre for 300 acres -- direct-cut harvesting.

7. FORAGE SYSTEMS INCLUDING FIELD CURING

7.1 Program Inputs

7.1.1 Initial method alternatives -- In terms of numbers of alternatives, forage handling methods incorporating some field curing of the forage constitute the greater proportion of all forage handling method alternatives. Either equipment or the end product could be used as a criterion for further subdivisions in the total network. Following the preliminary section of the network are sections dealing with wilted alfalfa silage and haylage (see figure 21), bales (see figure 22), bulk hay (see figure 23), and cubes or wafers (see figure 24).

System alternatives having wilted alfalfa silage or haylage as their end product are listed in Appendix H.

Note: A test was made at node 100 ensuring that node 103 was chosen if haylage had been selected, or presenting three alternatives if wilted alfalfa silage had been chosen. In the same vein, where dump transports were used and a forage blower was selected, a long conveyor-type hopper was required. There were 6730 possible routes with the least likely having a probability of 1/12,096 or 0.000083 of being chosen. Eliminating nodes 91 through 99 would reduce the possible routes to 1344 alternatives (see section 4.2).

In the Edmonton area, most farmers put up wilted alfalfa silage and haylage into tower silos, to be mechanically unloaded at a later date. In order to prevent knitting of forage and consequently unloading difficulties, the forage must be chopped short before storage (62). This requirement eliminates flail-type harvesters from the list of alternatives. Therefore, in the simulation program, the crop was

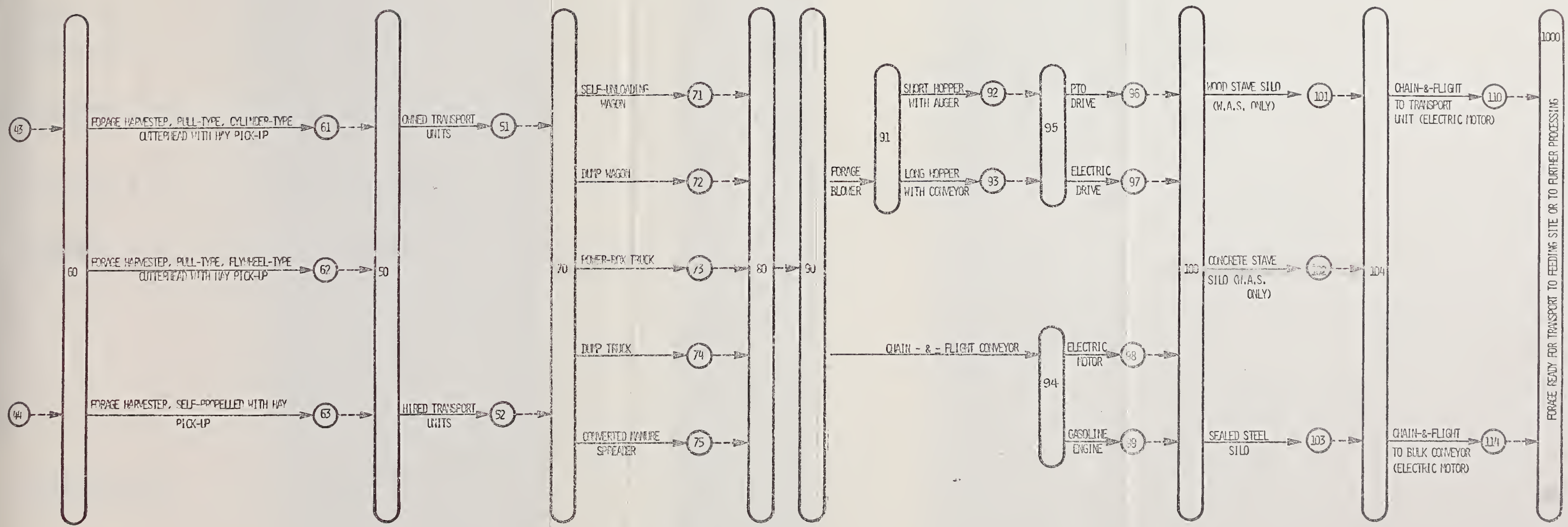


Figure 21. Haylage and wilted-alfalfa silage network section.

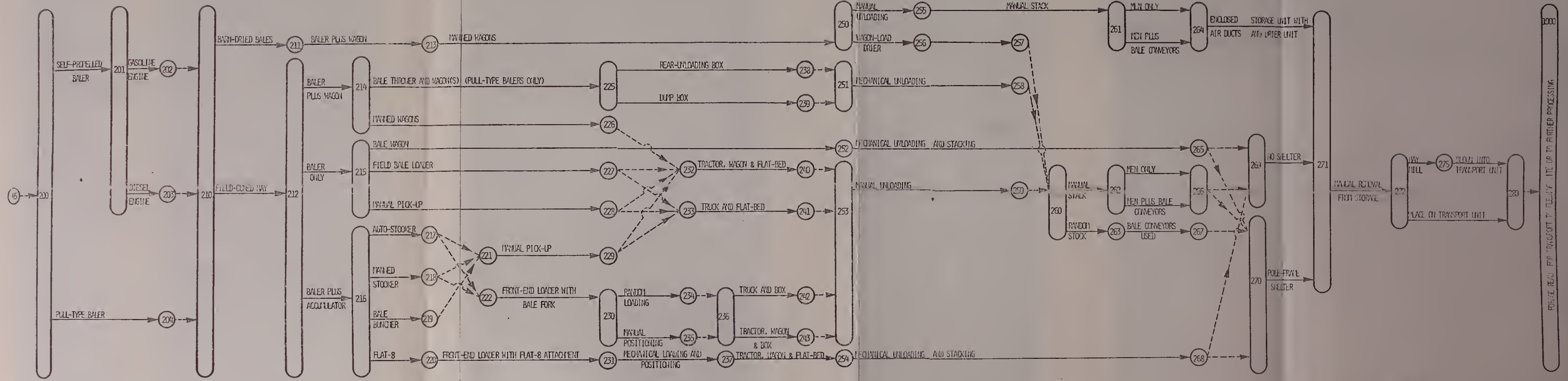


Figure 22. Bales network section.

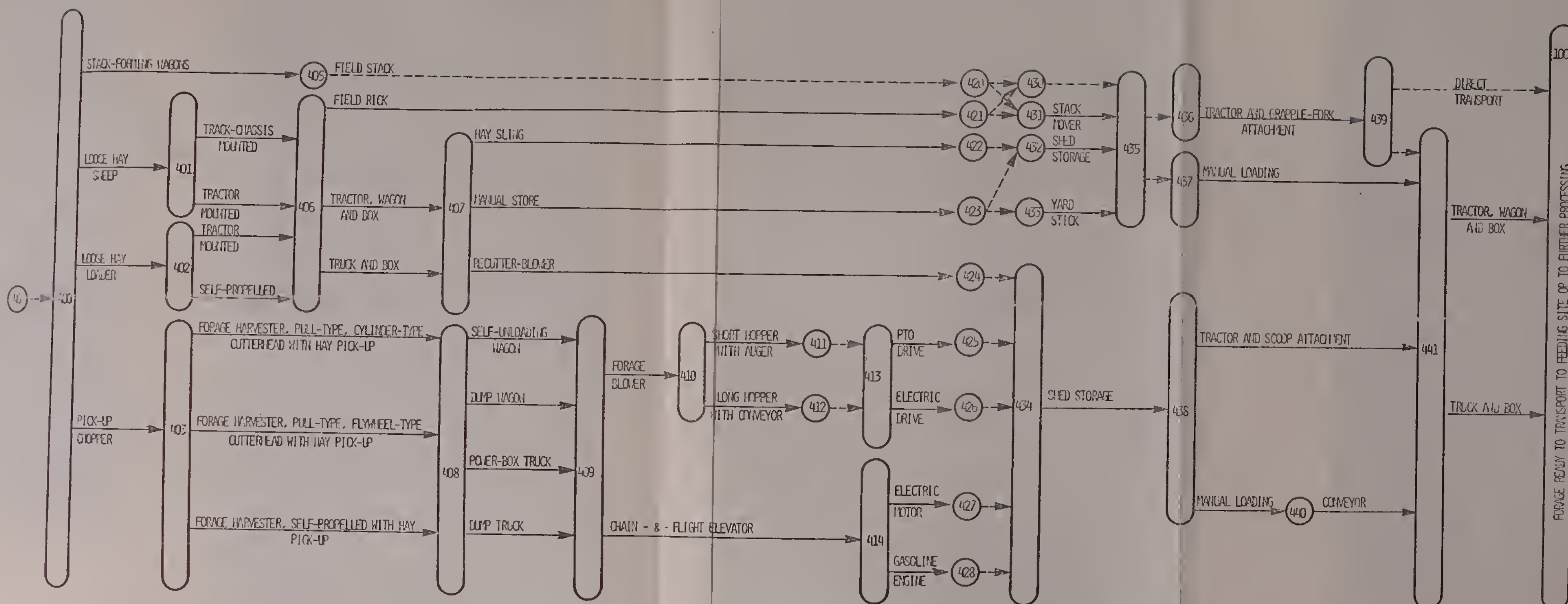


Figure 23. Bulk hay network section.

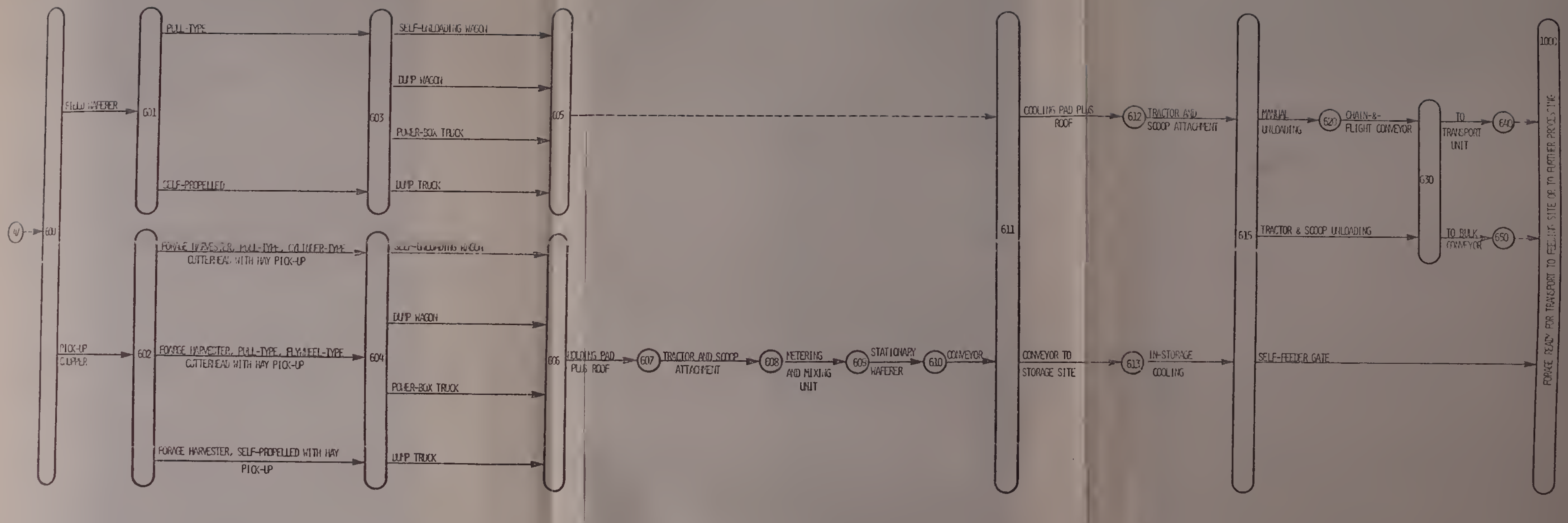


Figure 24. Cubes or wafers network section.

chopped and blown into transport units by a forage harvester equipped with a hay pick-up and either a cylinder- or a flywheel-type cutterhead (more on this later).

7.1.2 Some functions -- FUNCTIONS 1 through 5 are identical to those used in the first GPSS program, and are described in section 6.1.2. FUNCTIONS 8 and 10 are the same as those described in section 6.1.2 with the exception of one or two changed values.

Loss functions were taken from Weller's (127) tables. FUNCTION 6 gave field losses, FUNCTION 9 gave storage losses for unsealed tower silos and FUNCTION 7 gave storage losses for hermetically sealed tower silos. The seepage, fermentation and surface loss figures given in table 10 and table 11 were lumped together to give the storage losses listed in FUNCTIONS 9 and 7, respectively. For example, the Materials Handling Manual (124) summarized several research reports, stating that from 2% to 4% dry matter loss can be expected when using gas-tight silos, and an average of 10% with conventional tower silos.

7.1.3 Forage harvesters -- Moisture content figures used for wilted alfalfa silage and haylage ranged from 55% to 70% and 40% to 50% (wet basis), respectively. The power requirements were set at 2.5 and 3.0 pto hp-hr/ton DM, respectively. These approximations, taken from the graph given by Bainer, Kepner and Barger (5), corresponded to a $\frac{1}{2}$- to $\frac{1}{4}$-inch theoretical length of cut. Using the appropriate power coefficient, the power-dependent rate of harvesting was calculated and then compared to the width-dependent rate, the limiting rate to be used as a constant for the remainder of the year being simulated. Efficiencies and forward speeds used in the above calculations were the

TABLE 12. DRY MATTER LOSSES FOR UNSEALED TOWER SILOS

Moisture Content (% w.b.)	Field Losses (% DM)	Seepage Losses (% DM)	Fermentation Losses (% DM)	Surface Losses (% DM)	Total Losses (% DM)
85	2	10	10	3	25
80	2	7	9	3	21
75	3	3	8	4	18
70	3	1	7	4	15
65	4	0	8	5	17
60	6	0	9	5	20

TABLE 13. DRY MATTER LOSSES FOR HERMETICALLY SEALED TOWER SILOS

Moisture Content (% w.b.)	Field Losses (% DM)	Seepage Losses (% DM)	Fermentation Losses (% DM)	Surface Losses (% DM)	Total Losses (% DM)
85	2	10	10	0	22
80	2	7	9	0	18
75	3	3	8	0	14
70	3	1	7	0	11
65	4	0	6	0	10
60	6	0	5	1	12
50	10	0	4	2	16
40	13	0	4	3	20

same as those used in section 6.1.3. The width used in the second calculation was the maximum width of cut for the cutting machine used. The shorter length of chop made for greater storage density as well as easier mechanical handling. As with direct-cut forage harvesters, forage harvesters equipped with hay pick-ups were treated as having equal capacity but were differentiated on a cost basis.

In Western Canada, few farmers if any use tedders, and few flail-type mowers are sold. Both of these types of machines were excluded from the network of alternatives incorporated into the second GPSS program. Flail mowers could be excluded because of their tendency to leave relatively few strands of grass in the swath lying parallel and at right angles to the knives (111). This tendency results in less regular length of cut and gives a negative bias for using flail mowers in any system demanding short and uniform length of cut. Tedders could be excluded for their similar tangling effect (111). According to Hundtoft (61), the optimal moisture content for tedding is about the same as for raking -- another argument for not using a tedder.

7.1.4 Weather analysis -- Any forage system including some field curing of the forage is liable to weather penalties. The object is obviously to maximize the drying rate by using the optimal mechanical treatment to minimize the time of exposure to the elements. Various studies have indicated the relative merits of different mechanical treatments for specific regions and weather conditions but have not related drying rates to meteorological data. Goss, Kepner and Jones (53), Hall (57) and Dudar (44) ranked different treatments for their specific areas. Dudar's (44) conclusion that the effect of conditioning on drying rate is not very pronounced when drying conditions are poor, only emphasizes the need for relating drying rates to weather data. In addition, the relationship between rains and leaching losses has been recognized and the effects of bleaching and fermentation on carotene and on soluble carbohydrate losses have been appreciated (12), but not suitably quantified for simulation.

Work by Brück and van Elderen (19) and preliminary work by Kemp, Misener and Roach (71) indicated that latent evaporation may be used as a criterion for forage drying once the relationship is established.

Several studies have indicated that a subjective and arbitrary set of weather criteria may be successfully used in establishing 'good' and 'bad' days for forage drying. Graphs given by Hall (57) and by Kurtz and Bilanski (75) have shown the rather marked effect of the diurnal cycle and the drying advantages one might expect from cutting forage before the dew has disappeared. Pedersen and Buchele (98), conducting laboratory tests on alfalfa drying rates, noted that nearly all the stomata closed after 3 hours of drying at which time the evaporation rate levelled out. Working in the Fraser Valley of British Columbia, Jeffers (67) found that arbitrary weather criteria proved satisfactory for selection of optimal haying machinery.

For this cost-benefit simulation, cumulative probability curves for 'good' and 'bad' drying days were used, these curves arrived at by analyzing historical weather data for the calendar periods of the first and second cuttings. A particular day was classified as a 'good' or a work day provided it passed one of the following sets of criteria.

Set A: (1) at least 75% of the total daylight hours are bright sunshine.

(2) precipitation is less than 0.05 inch for the day.

(3) precipitation is less than 0.50 inch for the previous day.

Set B: (1) precipitation is less than or equal to 0.01 inch for the day.

(2) precipitation is less than 0.1 inch for the previous day.

(3) average windspeed at six feet is greater than 10 mph.

(4) daily mean dew-point temperature is in excess of 10^{o}F. below the daily mean temperature.

The results are graphed in figures 25 and 26. A comparison with figures 27 and 28, where rainfall was the only criterion, points out the fact that a measure of evaporation might be more indicative of a particular day's hay-drying potential. Cumulative rainfall probabilities (see figure 29) would be of little use unless some indication of rainfall intensity (126) as well as some rewetting function for the forage were available. One of the goals of this study was to pinpoint, if possible, such 'hazy' areas as being critical or non-critical in determining optimum systems.

Once a sequence of work days had been generated, a set pattern of events was assumed on a daily basis: cut, wilt and harvest. The cutting would be done in the early to mid morning hours so as to make best use of the drying day. The assumption made was that the cutting unit or cutting and raking units could windrow one day's supply in the morning or could at least maintain a lead on the harvester unit. (An examination of Appendix C supports this assumption.) Note that several deviations from reality have occurred in this section of the simulation.

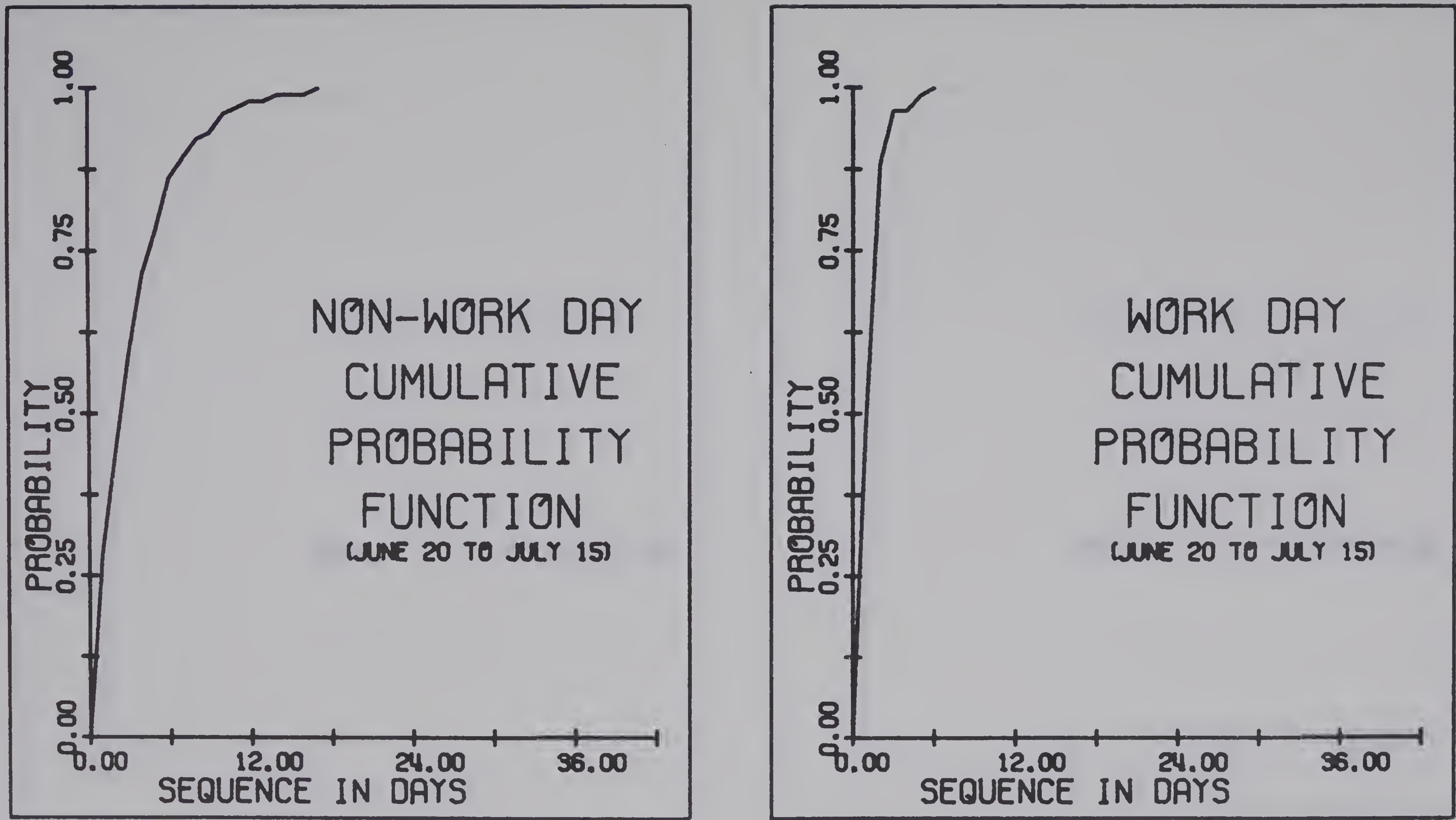
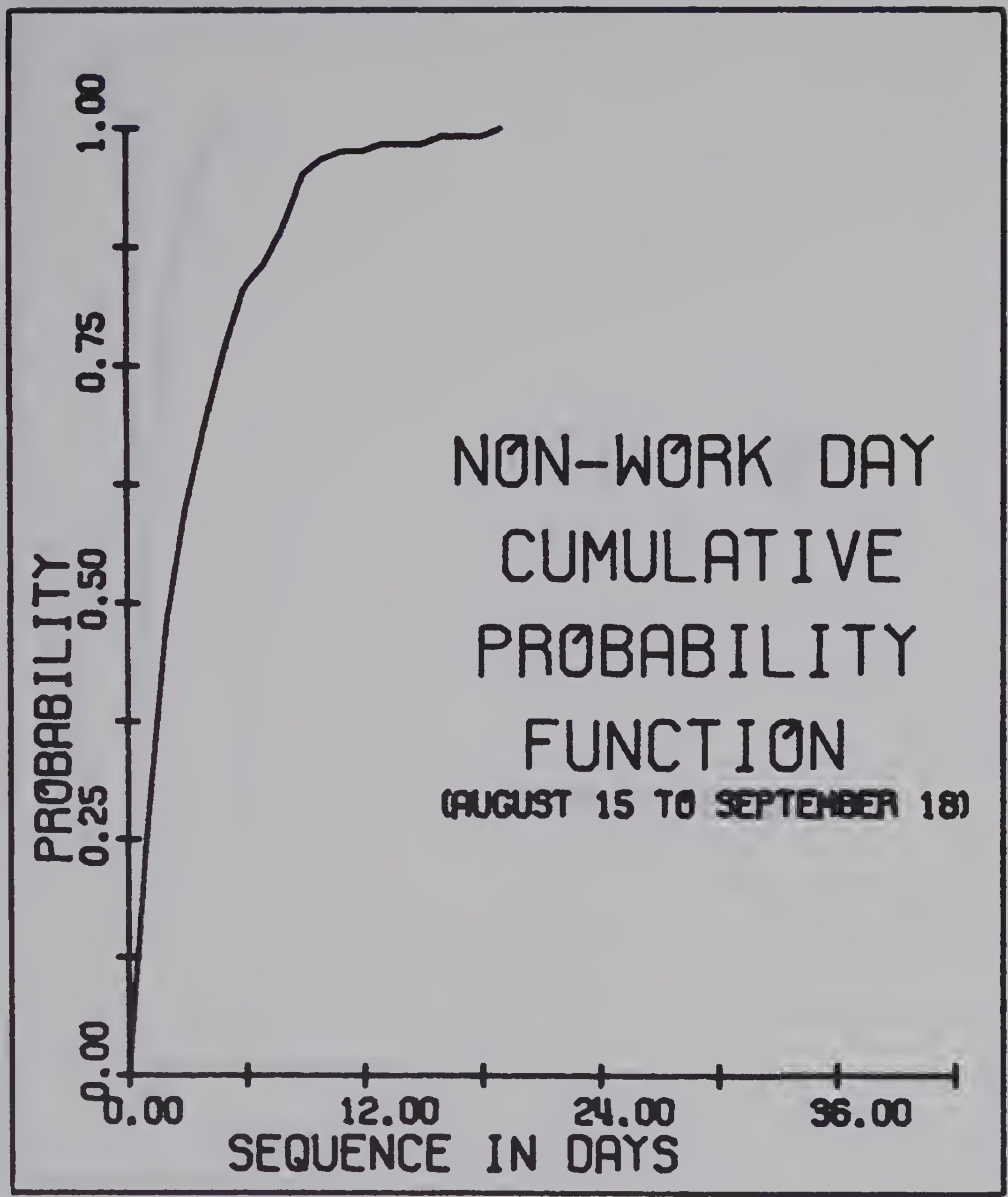


Figure 25. Weather-dependent cumulative probabilities - first cut (arbitrary drying criteria).



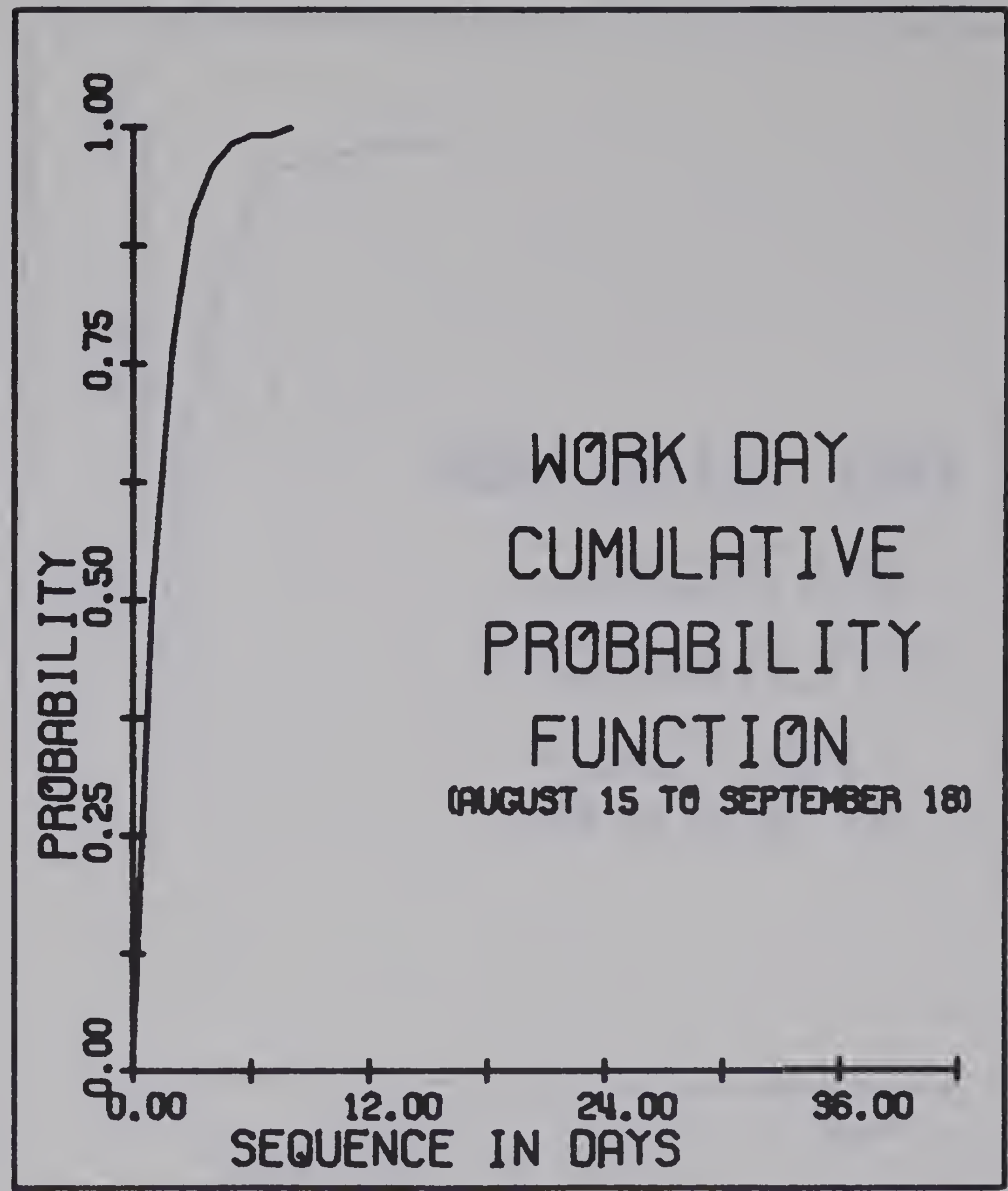


Figure 26. Weather-dependent cumulative probabilities - second cut (arbitrary drying criteria).

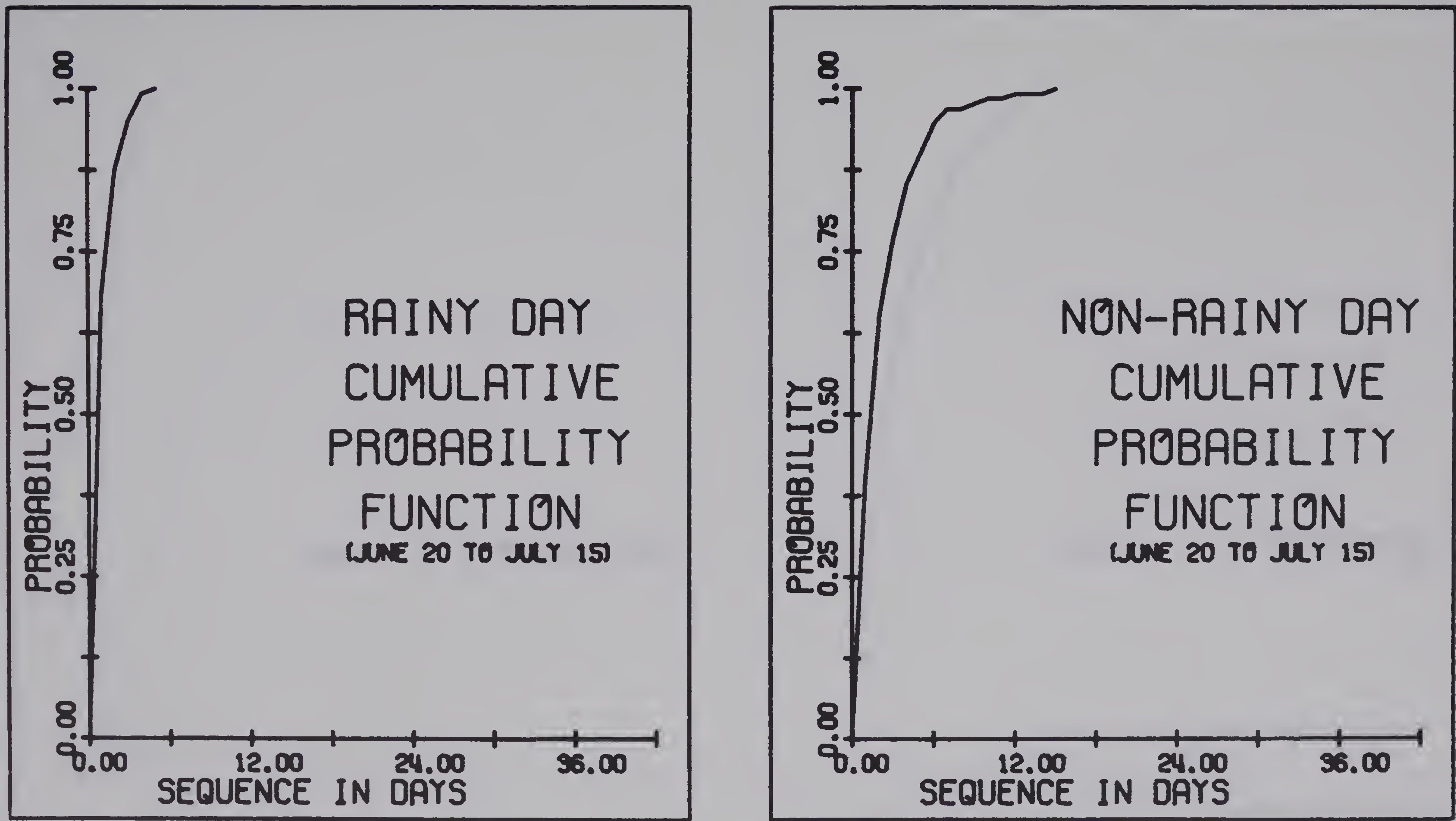
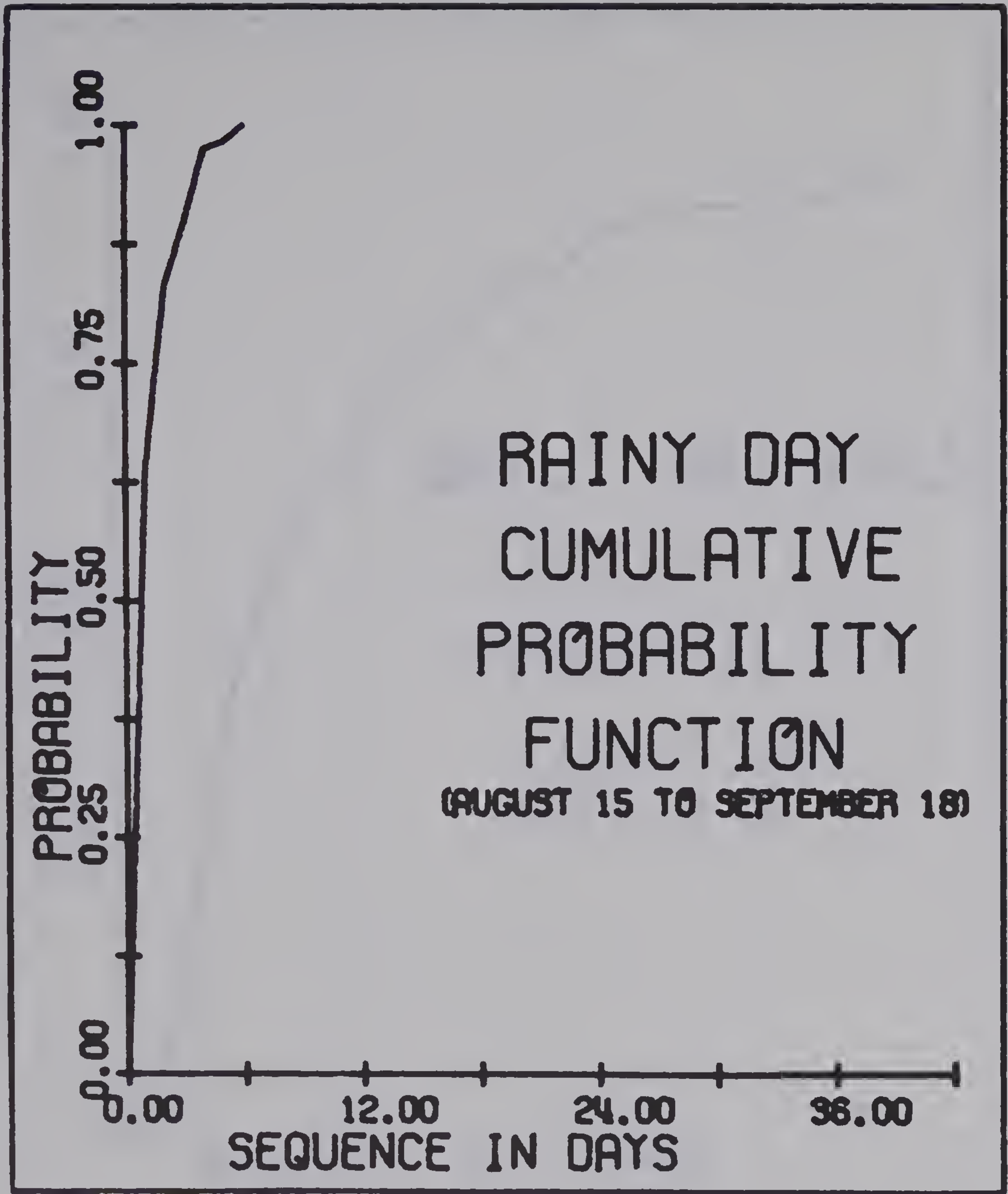


Figure 27. Weather-dependent cumulative probabilities - first cut (rainfall criterion).



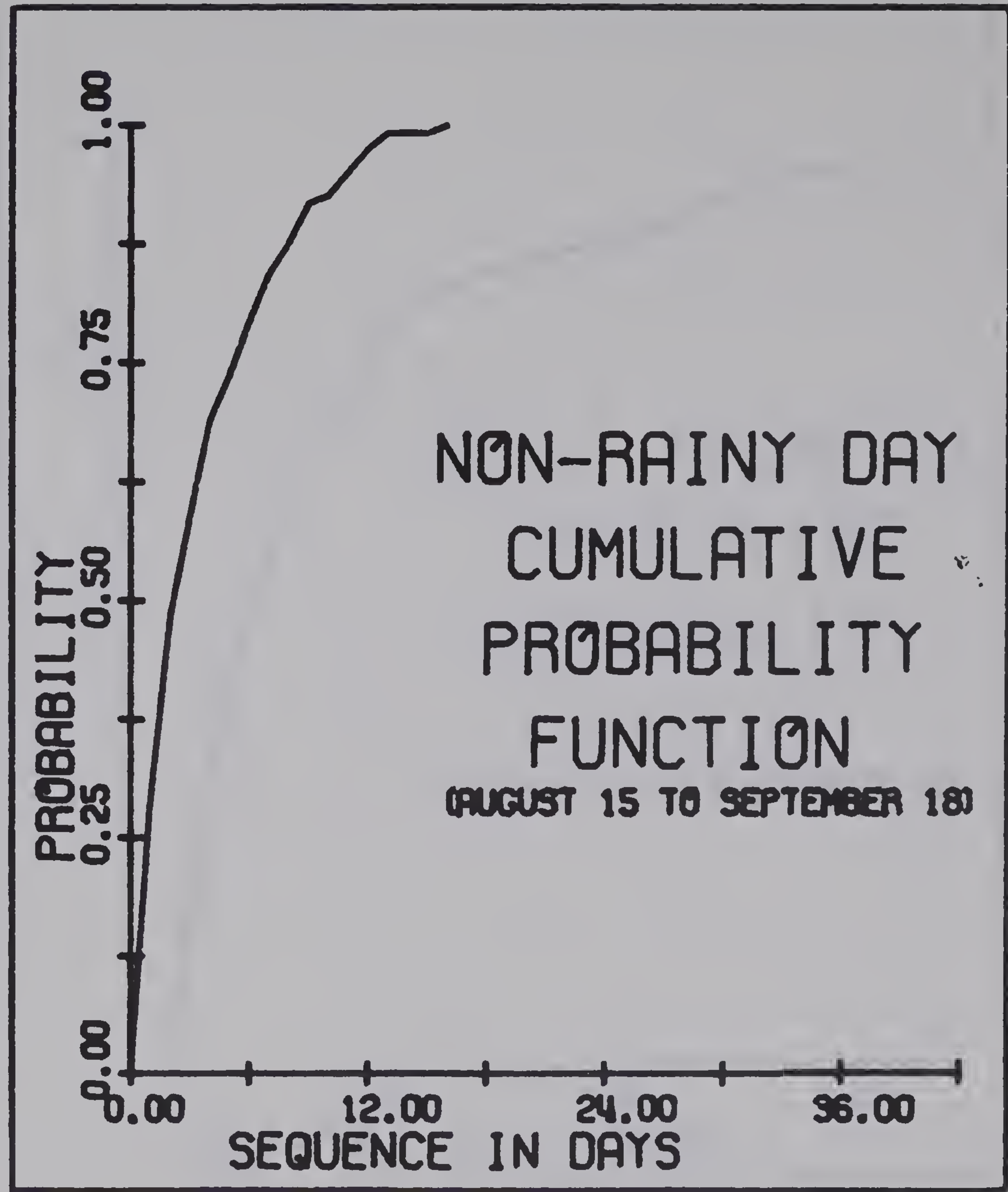


Figure 28. Weather-dependent cumulative probabilities - second cut (rainfall criterion).

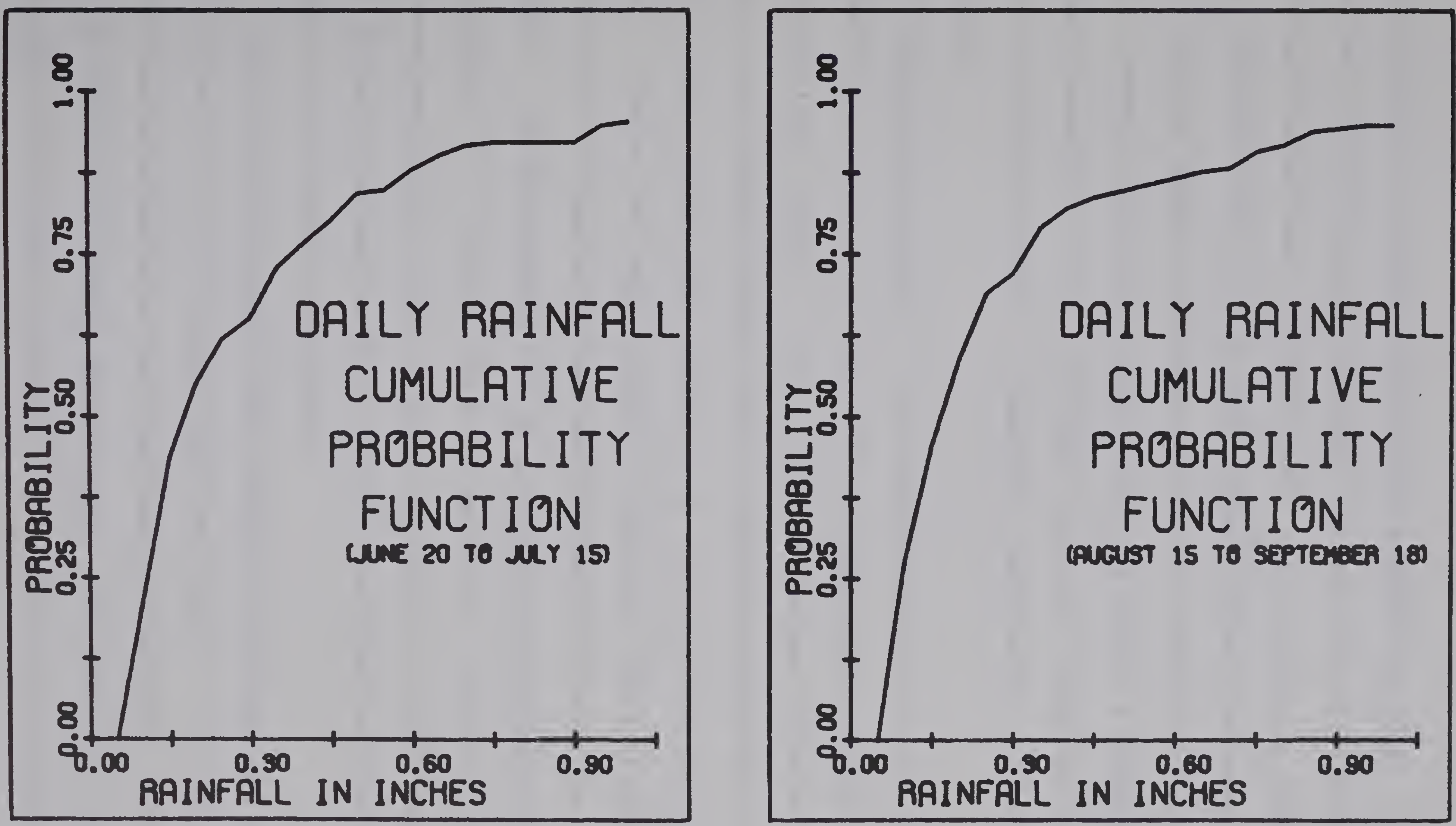
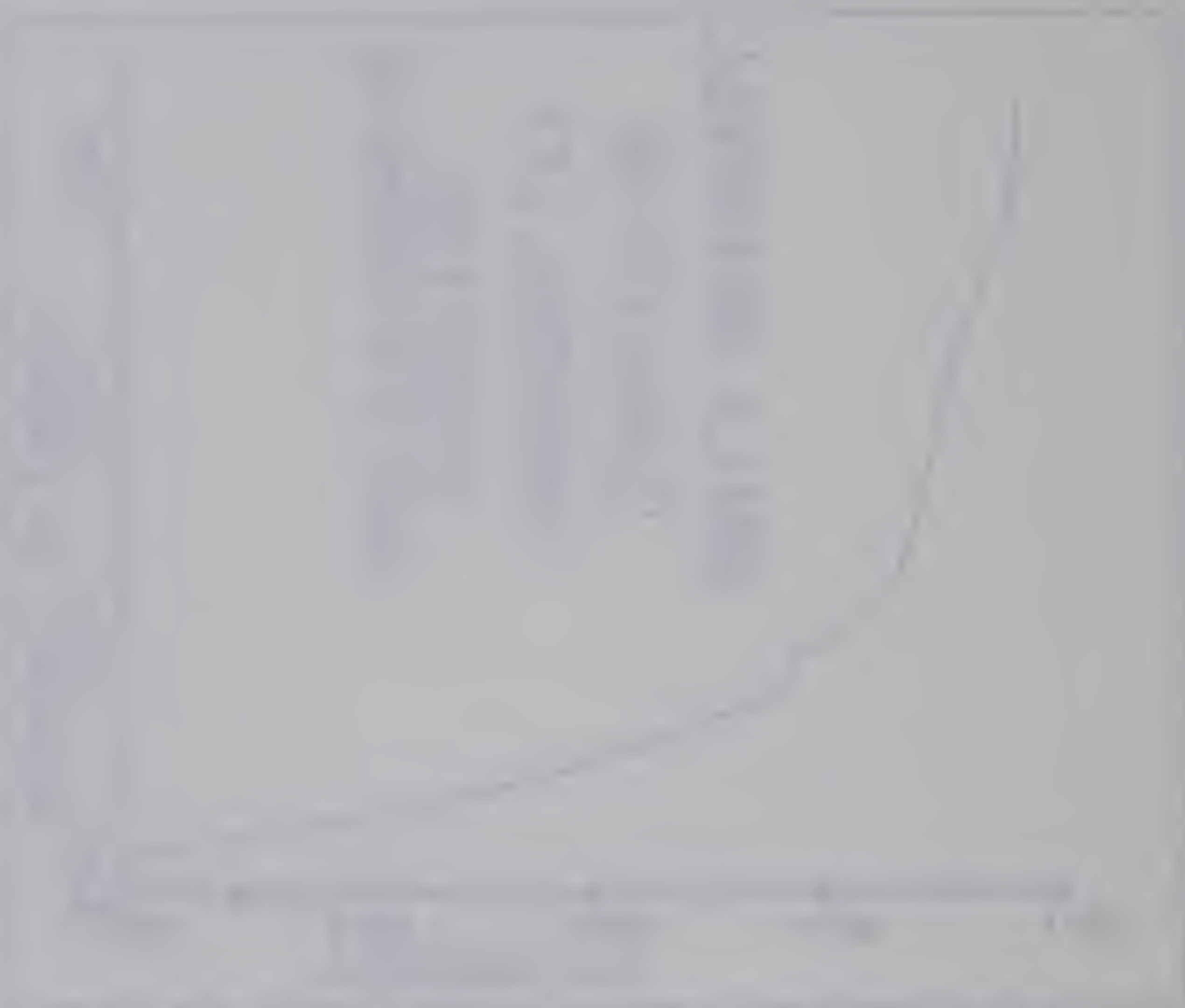


Figure 29. Cumulative rainfall probabilities during the two haying periods.



The possibility of scheduling difficulties has been set aside. Labour costs for cutting/windrowing operations have been calculated on a total-hours basis rather than a man-days basis. No allowance has been made for a different drying rate for each cutting-windrowing technique, nor for a different number of working hours per day from one day to the next. However, all of these issues would only lead to a decrease in the daily capacity or a rise in variable costs and a subsequent bias against the pre-cut methods -- a mandatory consideration in the analysis to follow.

7.1.5 Blowers and conveyors -- Two alternative ways of putting the chopped forage into the silos are: (1) by forage blower, and (2) by chain-and-flight conveyor. Bainer, Kepner and Barger (5) noted that length of cut, forage moisture content, peripheral speed of the fan, and height of silo all have some bearing on the elevating efficiency of the blower. Complex and largely unknown relationships make a single figure, such as used in forage harvesting, more desirable for simulation purposes. The ASAE Yearbook (48) gives the power requirements of the forage blower as 1 - 1½ hp-hr/ton of wet material. In view of the fact that some manufacturers claim a maximum capacity of 1 T./min., a range of 60 to 100 pto hp was used in this simulation, the actual point chosen randomly for any specific transaction.

Blower pipe requirements would normally be five feet less than the height of the silo, plus necessary elbows and a spout. For this study, the cost was calculated on a flat linear rate and the height of the silo plus one foot used as a length approximation. Silo height was taken as being equal to the nominal height of the silo plus any above-ground base

or foundation that was specified. For the particular case of the horizontal sealed silo, a piping requirement of height plus radius plus two feet was specified in the simulation program.

The chain-and-flight conveyor elevator presents a valid alternative to the forage blower. Richey (104) stated that "Elevators up to 65 feet in length may be used to elevate silage into vertical silos. They are operated at angles up to 70^{o} ..., handling silage at 20 tons per hour with a 3-hp electric motor in many cases." Dobie (40) gave an example of a 42-foot elevator filling a 35-foot silo. Utilizing a 5-hp motor with the 2" x 4" cross flights moving at 260 fpm, the conveyor could handle the output of a forage chopper working steadily.

Only one particular size and make was used in this program. A 62-foot model (largest of the line) with 3" x 21" flights spaced 14 inches apart was used. Given a maximum angle of elevation of 70^{o} with one foot of conveyor allowed for clearance, a 57-foot silo could be filled providing an auxiliary cross-conveyor was used. The range of speeds used was the one indicated by the Materials Handling Manual (24) as the normal range, 75 to 125 fpm. Cubic capacities depend on the angle of elevation and the angle of repose. The author could not find any reference to studies conducted in the area of angle of repose for silages. If one could use the estimations given by Neubauer and Walker (93) of 60^{o} for chopped hay at six to ten pcf and of 80^{o} for long hay at four pcf as guidelines, then the angle of repose would vary with length of cut and moisture content. The angle of repose for chopped forage would likely exceed that of chopped hay because of the added

cohesion contributed by the moisture. But another consideration is the vibration of the conveyor unit which may shake the material down to a lower effective angle of repose. In accord with the 20 T./hr figure given by Richey (104) and with a view to minimizing the favourable bias for such a low-power system, the function giving the lowest capacity of the six listed in Appendix H was used. Even with these estimates of 40° for the angle of repose, a maximum flight volume of level full, and four pcf dry-matter density, the capacity figures ranged from 1.0 to 7.6 T. DM/hr, depending on the speed and angle of elevation. If wilted alfalfa silage was stored at 65% moisture content, 7.6 T. DM/hr would be equivalent to about 21.7 T. WM/hr. FUNCTION 21 was used for both wilted alfalfa silage and haylage (see Appendix C for a more detailed description of volumetric calculations).

In the particular case of the curvet silo, the same 62-foot conveyor was used but care was taken in calculating angle of elevation to ensure a minimum separation from the structure of 1 foot (more on this in section 7.1.7). FUNCTION 21 was applied as previously described.

7.1.6 Tower silos and unloaders -- FUNCTIONS 13 through 19, listed in Appendix H, relate to tower silos and horizontal sealed silos. These types of silos were the only ones considered for wilted alfalfa silage and haylage in accord with general practice and with limitations of the loss functions described in section 7.1.2. As indicated in figure 11, three types of construction were considered: wood stave, concrete stave and steel or glass-lined steel silos. Because haylage is so dependent on good managerial practice, the program made sure that haylage would be stored only in a sealed silo. After the type of silo had been decided

upon, the alternative sizes were presented for random selection. Although these sizes did not include every possibility available in the Edmonton area, they did span the range of possibilities. The required storage space was determined on the basis of 1 1/3 fillings per year for each silo -- a calculation procedure used by silo company representatives in the area. A farmer contemplating purchase of one or more tower silos would likely take into account the head of livestock to be fed, their ration, the number of acres of forage, expected yields, and future expansion. In all likelihood, he would buy the largest silo size meeting his requirements so as to minimize investment per ton of capacity. Obviously, for the general situation portrayed in this simulation, a different approach was required. Once the particular size had been chosen, the number of such silos required to provide sufficient storage capacity was calculated. For records of total outlay for storage facilities, initial constructed costs were used. However, annual costs were calculated per ton of dry matter capacity rather than per ton of dry matter stored. In other words, unused storage space was not penalized.

Intuitively, a drop in silage density with a decrease in moisture content would be expected on a dry matter as well as a wet matter basis. Shepperson and Corrie (111) approximated tower silage densities as 15 to 20 lb DM/ft^3. Hundoft and Guest (62) indicated that a switch from wilted silage at 65% moisture content to haylage at 50% moisture content may reduce the dry-matter capacity of a tower silo by as much as 13%. Generally, however, there is little agreement on silo height and corresponding silage density (111).

For the GPSS program listed in Appendix H, dry matter densities and silo capacities were calculated using available references to high-moisture alfalfa silage at various settled depths. For shallower depths, figures given by Otis and Pomroy (96) were used; for taller silos, figures given in the Materials Handling Manual (124) were used. Table 12 indicates the similarity of the two sets of data at common depths of silage. Compaction of 10% was assumed, and 5 feet of side-wall were allowed for suspending a top unloader where such was required (123).

If manufacturers' estimated capacity figures in cubic feet were not available, nominal dimensions were used to estimate volumetric capacities. Full account was taken of height and space allowance for unloaders, either top or bottom, and central flues where required. Where necessary, the larger silo capacities in cubic feet were extrapolated from available data for shorter silos of the same diameter and manufacture.

The initial costs given in FUNCTION 14 are 1969 quotations for on-site erection in the Edmonton vicinity. These prices, given by local suppliers, include all costs except for silo unloaders in the case of wood or concrete silos. An interest rate (8%) and insurance rate (1%) were used in calculating per annum fixed costs. Repair costs were charged at 1.2% for wood and concrete silos and at 0.6% for steel silos. Straight-line depreciation rates of 5% and 2.5% were used for wood or concrete and for steel silos, respectively. These rates are maxima permitted for taxation purposes (21) but do not incorporate any obsolescence factor. Because initial costs of some silo unloaders were included in the total erected cost of the silo, per annum fixed costs of

TABLE 14. SILAGE DENSITIES IN TOWER SILOS

Depth of Settled Silage (ft)	Average Wet Matter Density For All Silage Below Depth Indicated (pcf)	Average Dry Matter Density For All Silage Below Depth Indicated (pcf)
2[a]	16.9	4.2
4	22.7	5.7
6	27.3	6.8
8	31.1	7.8
10	34.1	8.5
12	36.7	9.2
14	38.8	9.7
16	40.5	10.1
18	42.1	10.5
20	43.5	10.9
22	44.8	11.2
24	45.9	11.5
26	47.0	11.8
28	48.0	12.0
30	48.8	12.2
32	49.6	12.4
34	50.7	12.7
36	51.5	12.9
20[b]	35.0	10.5
25	38.2	11.5
30	41.4	12.4
35	44.2	13.3
40	46.9	14.1
45	49.5	14.8
50	51.8	15.5
55	54.0	16.2
60	56.1	16.8
65	58.0	17.4
70	59.8	17.9

[a]The first 18 lines were taken from Otis and Pomroy (96). The first cut alfalfa entered the silo at 72% to 78% average moisture content, and proved to have an uneven distribution in the silo. Conversions were based on a 75% mc (wet basis) figure.

[b]The latter 11 lines were taken from the Materials Handling Manual (124). Conversions were based on 70% mc (wet basis) grass silage.

all tower silo unloaders were calculated on the same basis as the silos they were to be used in. Where specific single-phase horsepower requirements were not given for a silo unloader, 5 hp was used if the diameter of the silo was less than 20 feet or $7\frac{1}{2}$ hp was used if greater than or equal to 24 feet. This demarcation closely approximates most unloader specifications.

Unloading rates were difficult to establish. Decker (36) observed 3.8 to 4.0 T./hr for 3 to $7\frac{1}{2}$ hp motor driven units unloading grass silage. Richey (104) gave the figures 60 to 100 lb/min for 2 to 5 hp units unloading grass silage. Freezing of the silage might well reduce the maximum unloader capacity. The range of 1.8 to 2.2 T./hr used in this analysis represents such a reduced rate. The blanket application of this rate to both wilted alfalfa silage and haylage introduced a small error but simplified this section of the program. Because availability of time and labour for unloading procedures was not specified (limitation due to boundaries of the analysis), unloading rates would not significantly influence the choice of components for the optimal system.

<u>7.1.7 Horizontal sealed silos and unloaders</u> -- FUNCTIONS 13 through 19, listed in Appendix H, include three different lengths of a steel, horizontal, curvet silo manufactured by one company. Storage requirements for haylage were determined as outlined in section 7.1.6. Figure 30 indicates the approximation for settled depth of silage -- the procedure used being the same as that for tower silos. The endwall area of the settled silage was approximated by

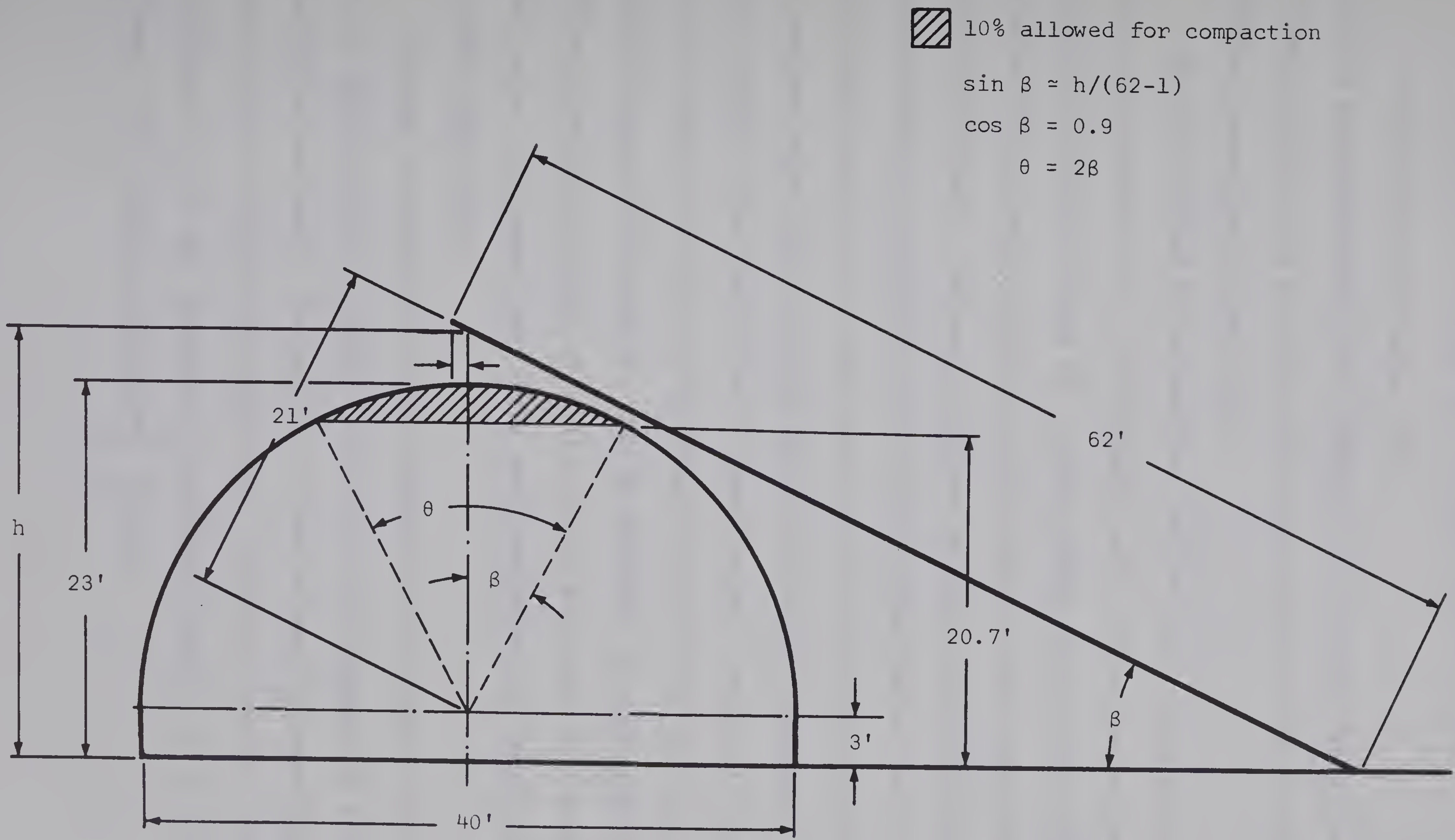


Figure 30 . Effective endwall of curvet horizontal silo.

$$E = (3\ \text{ft})(40\ \text{ft}) + \frac{\pi}{2}(20\ \text{ft})^2 - \frac{1}{2}(20\ \text{ft})^2(\theta - \sin\theta)$$

$$= 725\ \text{ft}^2 (\text{to the nearest ft}^2)$$

This area was multiplied by the lengths of the storage units (the lengths of panel sections were 61.5 feet, 82.0 feet and 105.9 feet) to give the effective capacities in cubic feet.

The costs quoted by the supplier included only the material costs of the silo and the cost of the unloader unit. Total erected costs were arrived at as shown in table 13. If the farmer could provide labour and supervision without contracting the erection, total costs would be reduced accordingly. Beginning with the shipping weights and the required materials indicated on the specification sheets, cost of construction materials were determined, based on contractor prices. The maximum hours listed on these sheets were used in estimating labour costs. Labour rates were Northern Alberta union rates as of October 1, 1969 for IBEW (International Brotherhood of Electrical Workers) and for unskilled construction workers. The 5% increment in price from 1968 to 1969 was a rough approximation of the rise in price due to increasing steel costs. Per annum fixed costs were charged on the same basis as for steel tower silos.

Because no research data were available on the type of unloader used in these silos, the range of 12 to 20 T./hr suggested by the manufacturer was used. The capacity of the 18-foot chain-and-flight conveyor used to elevate the forage into a transport unit was calculated (see section 7.1.5) and compared to the output capacity of the silo unloader. The limiting capacity set the pace.

TABLE 15. ERECTED COSTS OF HORIZONTAL SEALED SILOS

Cost Item	Small Unit			Medium Unit			Large Unit		
March 1, 1968 silo cost			$29,540			$32,280			$34,615
Add 5% for 1969 estimate			1,477			1,614			1,731
Shipping cost @ $1.11/100 lb			422			466			511
Materials									
- concrete del'd @ $18/yd^3	$1,440			$1,800			$2,160		
- wire mesh @ $45/1000 ft^2 for 6" x 6" 10/10 mesh	153			171			189		
- ½" Re-bar @ $8.10/100 ft and 0.688 lb/ft	157			188			220		
- Anchor bolts @ .38/ea. 1½" x 10" size	38			43			50		
SUBTOTAL		$1,788			$2,202			$2,619	
Labour									
- concrete @ $3.25/hr	$1,950			$2,275			$2,600		
- erection @ $3.25/hr	3,250			3,900			4,875		
- electrical @ $4.55/hr	127			146			164		
SUBTOTAL	5,327			6,321			7,639		
Add 15% for payroll, loading costs, etc.	799			948			1,146		
SUBTOTAL		$6,126			$7,269			$8,785	
Contractors Total Cost		7,914			9,471			11,404	
Add 15%		1,187			1,421			1,711	
Construction Cost			$9,101			$10,892			$13,115
5% contingency allowance			455			545			656
TOTAL APPROXIMATE ERECTED COST			$40,995			$45,797			$50,628

7.2 Optimum Systems

Forage systems incorporating some field curing were simulated at both the 200- and the 300-acre levels with a computer time limit of 30 minutes each, then grouped and ranked as described in section 6.2. There were 841 and 776 passes made through the network at the 200- and 300-acre levels respectively. The probabilities of selecting the least likely route ($p = 0.00013$) at least once were 0.108 and 0.096 for 200 and 300 acres respectively. The probabilities of selecting the least likely group of systems ($p = 0.002$) at least once were 0.827 and 0.802. The probabilities of at least two selections of this group dropped to about 0.5. Array sizes for ranking plotting were the same as those used for direct-cut harvesting systems.

Tables 16 and 17 indicate the field machinery used in each of the ranked groups of passes (essentially different systems), the system number corresponding to its position in the ranked groups. These numbers are identical to those used on the X-axes of figures 31 to 40.

The slight cost advantage of wilted-grass silage systems over haylage systems disappeared as the acreage changed from 200 to 300 acres. There was a marked preference for a once-over method of cutting and collecting forage at both acreage levels with the SP windrowers higher on the list at 300 than at 200 acres. In view of the assumptions made in section 7.1.4, the savings in labor and operating costs more than compensated for the increased depreciation and repair costs. Should the same windrower be used in the grain harvest, some of the depreciation and repair costs could be attributed to the grain enterprise, thus making the windrower an even more advisable choice from a cost, if not a field losses, aspect. Extended drying rates and consequent increased

TABLE 16. FORAGE MACHINERY SYSTEMS GRAPHED FOR 200 ACRES - PRE-CUT HARVESTING[a]

Machinery System Number(s)	End Product		Cutting and Collecting Equipment						Forage Harvester			Transport Source		Transport Type			
	WG SLG	HAYLAGE	MOWER	WL RAKE	SD RAKE	MULTI	SPWC	SPW	PT CYL	PT FLY	SP	OWNED	HIRED	SUW	DPW	PBT	DPT
1-3	x							x		x			x	x			
4-5	x						x		x				x		x		
6-9	x							x	x				x	x			
10-13	x					x			x				x		x		
14-19	x						x		x				x	x			
20-25		x						x		x			x		x		
26-30	x							x		x			x		x		
31-34		x					x			x			x	x			
35-37	x							x	x			x			x		
38-41		x				x			x				x		x		
42-46	x							x		x		x		x			
47-51		x						x		x		x		x			
52-58	x							x			x		x		x		
59-61		x					x			x		x		x			
62-65		x					x		x				x	x			
66-68	x					x				x			x		x		
69-71	x							x		x		x			x		
72-75	x							x	x				x			x	
76-79		x						x	x				x		x		
80-83		x					x		x				x		x		
84-90	x							x	x			x		x			
91-94	x						x			x			x		x		

TABLE 16. (continued)

Machinery System Number(s)	End Product		Cutting and Collecting Equipment						Forage Harvester			Transport Source		Transport Type			
	WG SLG	HAYLAGE	MOWER	WL RAKE	SD RAKE	MULTI	SPWC	SPW	PT CYL	PT FLY	SP	OWNED	HIRED	SUW	DPW	PBT	DPT
95-96	x						x			x		x		x			
97-100		x						x	x			x		x			
101-103	x					x			x			x		x			
104-107	x						x				x		x	x			
108-110		x						x		x		x			x		
111-114	x						x			x			x			x	
115-117	x					x				x		x			x		
118-122	x						x			x			x	x			
123-126		x						x		x			x				x
127-131		x						x		x			x	x			
132-137		x					x			x		x			x		
138-141		x						x	x				x	x			
142-145	x						x			x			x				x
146-149	x					x			x			x			x		
150-151	x		x		x				x				x	x			
152-153		x				x				x			x	x			
154-157	x					x			x				x	x			
158-162	x						x		x			x			x		
163-167	x							x		x			x				x
168		x					x		x			x			x		
169-172	x					x				x			x			x	
173-178		x						x	x			x			x		
179-192	x							x			x		x	x			

TABLE 16. (continued)

Machinery System Number(s)	End Product		Cutting and Collecting Equipment						Forage Harvester			Transport Source		Transport Type			
	WG SLG	HAYLAGE	MOWER	WL RAKE	SD RAKE	MULTI	SPWC	SPW	PT CYL	PT FLY	SP	OWNED	HIRED	SUW	DPW	PBT	DPT
183-185	x		x	x					x				x				x
186-189		x					x			x			x		x		
190		x	x	x					x				x	x			
191-193		x				x			x				x	x			
194-197		x	x		x				x				x				

[a] LEGEND:

WG SLG - wilted grass silage
WL RAKE - wheel rake
SD RAKE - side-delivery rake
MULTI - multi-treatment machine
SPWC - self-propelled windrower with attached conditioner
SPW - self-propelled windrower
PT CYL - pull-type with cylinder-type cutterhead and with pickup
PT FLY - pull-type with flywheel-type cutterhead and with pickup
SPW - self-propelled with pickup
SUW - self-unloading wagon
DPW - dump wagon
PBT - power-box truck
DPT - dump truck

TABLE 17. FORAGE MACHINERY SYSTEMS GRAPHED FOR 300 ACRES - PRE-CUT HARVESTING[a]

Machinery System Number(s)	End Product		Cutting and Collecting Equipment						Forage Harvester			Transport Source		Transport Type			
	WG SLG	HAYLAGE	MOWER	WL RAKE	SD RAKE	MULTI	SPWC	SPW	PT CYL	PT FLY	SP	OWNED	HIRED	SUW	DPW	PBT	DPT
1-2	x						x		x				x		x		
3-6	x							x	x				x	x			
7-9	x							x		x			x	x			
10-12		x					x			x		x		x			
13-17	x							x		x			x		x		
18-20	x							x	x			x			x		
21-24		x					x			x			x	x			
25-30		x						x		x			x		x		
31-37	x							x			x		x		x		
38-42		x						x		x		x		x			
43-47	x						x		x				x	x			
48-51	x						x				x		x		x		
52-55	x							x	x				x			x	
56-69	x							x		x			x				x
60-66	x							x	x			x		x			
67-70		x				x			x				x		x		
71-75	x							x		x		x		x			
76-79		x						x		x			x			x	
80-83	x						x			x			x			x	
84-86		x					x		x				x		x		
87-88	x						x			x		x		x			
89-92		x					x		x				x	x			
93-97	x						x		x			x			x		

TABLE 17. (continued)

Machinery System Number(s)	End Product		Cutting and Collecting Equipment						Forage Harvester			Transport Source		Transport Type			
	WG SLG	HAYLAGE	MOWER	WL RAKE	SD RAKE	MULTI	SPWC	SPW	PT CYL	PT FLY	SP	OWNED	HIRED	SUW	DPW	PBT	DPT
98-100	x						x				x		x	x			
101-103		x						x		x		x			x		
104-107	x						x				x		x			x	
108-111		x					x			x			x				x
112-114	x							x		x		x			x		
115		x					x		x			x			x		
116-119	x					x			x				x		x		
120-123		x						x	x				x	x			
124-127		x						x	x				x		x		
128-131		x						x		x			x	x			
132-137		x	x		x				x				x	x			
138-141		x						x			x		x	x			
142-145		x						x	x				x			x	
146-148	x		x	x					x				x				x
149-155		x					x		x				x			x	
156-158	x					x			x			x		x			
159-161		x					x				x	x			x		
162-165	x							x			x		x	x			
166-169		x						x	x			x		x			
170-172		x				x					x		x	x			
173-176		x					x			x			x		x		
177-178	x							x	x			x				x	
179-183		x					x			x		x			x		

TABLE 17. (continued)

Machinery System Number(s)	End Product		Cutting and Collecting Equipment						Forage Harvester			Transport Source		Transport Type			
	WG SLG	HAYLAGE	MOWER	WL RAKE	SD RAKE	MULTI	SPWC	SPW	PT CYL	PT FLY	SP[a]	OWNED	HIRED	SUW	DPW	PBT	DPT[a]
184-185	x							x	x				x				x
186-187	x		x		x				x				x	x			
188-191	x						x			x			x				x
192-194	x					x				x			x		x		
195-199	x						x			x			x	x			
200-201	x					x				x			x		x		

[a] See table 16 for legend.

weathering of forage, might well negate this cost benefit of using a windrower when penalty costs comprise a significant portion of the total cost (more on this later). As with direct-cut harvesting systems, pull-type forage harvesters preceded self-propelled units. The difference in cost between cutterhead types did not evidence itself in terms of the entire system. Hiring again appeared preferable to owning transport units provided they were available when required. Note that the optimal pre-cut systems selected wagons as opposed to trucks, whereas the optimal direct-cut systems made no such distinction (see tables 10 and 11). Since fewer years of weather were simulated for each pre-cut harvesting method than for each direct-cut harvesting method, the probability of inaccuracy in the ranking of system groups is greater for the former.

In figure 31, forage system costs are plotted for the first 200 of the ranked pre-cut systems with acreage set at 200 acres. These yearly costs are expressed in dollars per acre of land in forage. The high fixed to variable cost ratio accounted for the somewhat unrealistic total cost curve. As mentioned in section 6.2, high interest and depreciation rates could account for the excessively large fixed costs. Depreciation rates used were those permitted for income tax purposes and did not necessarily relate to the useful life of machines or structures that farm managers expect. In addition, some components of the system could serve as multi-purpose units in a real farming situation, thus relieving the forage program of some of these fixed costs. The inclusion of penalty costs in the total must not be forgotten either.

Figure 32 points out the extreme variations in harvest duration that can occur from one year to the next when the harvesting procedure

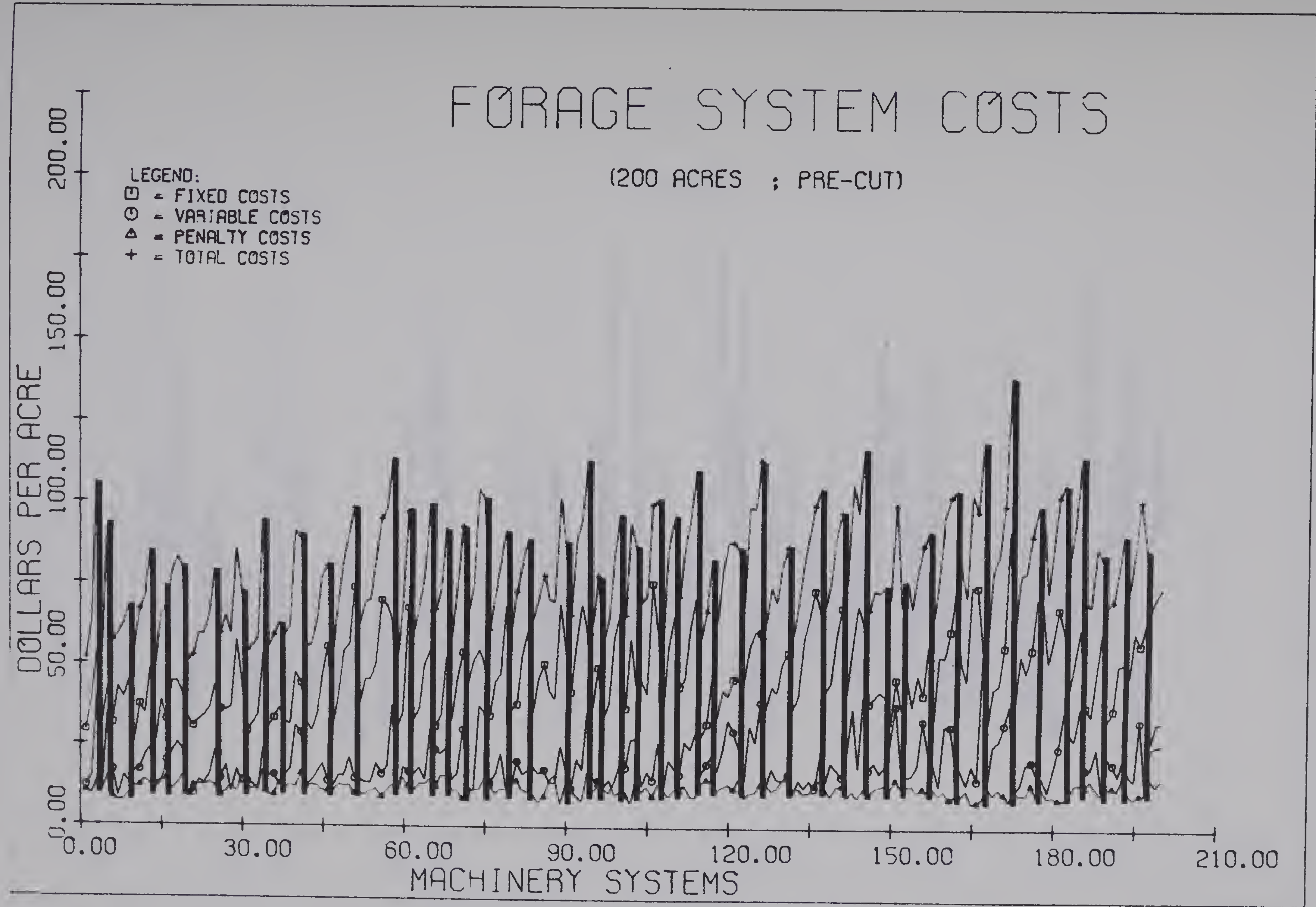


Figure 31. Forage system costs for 200 acres -- pre-cut harvesting.

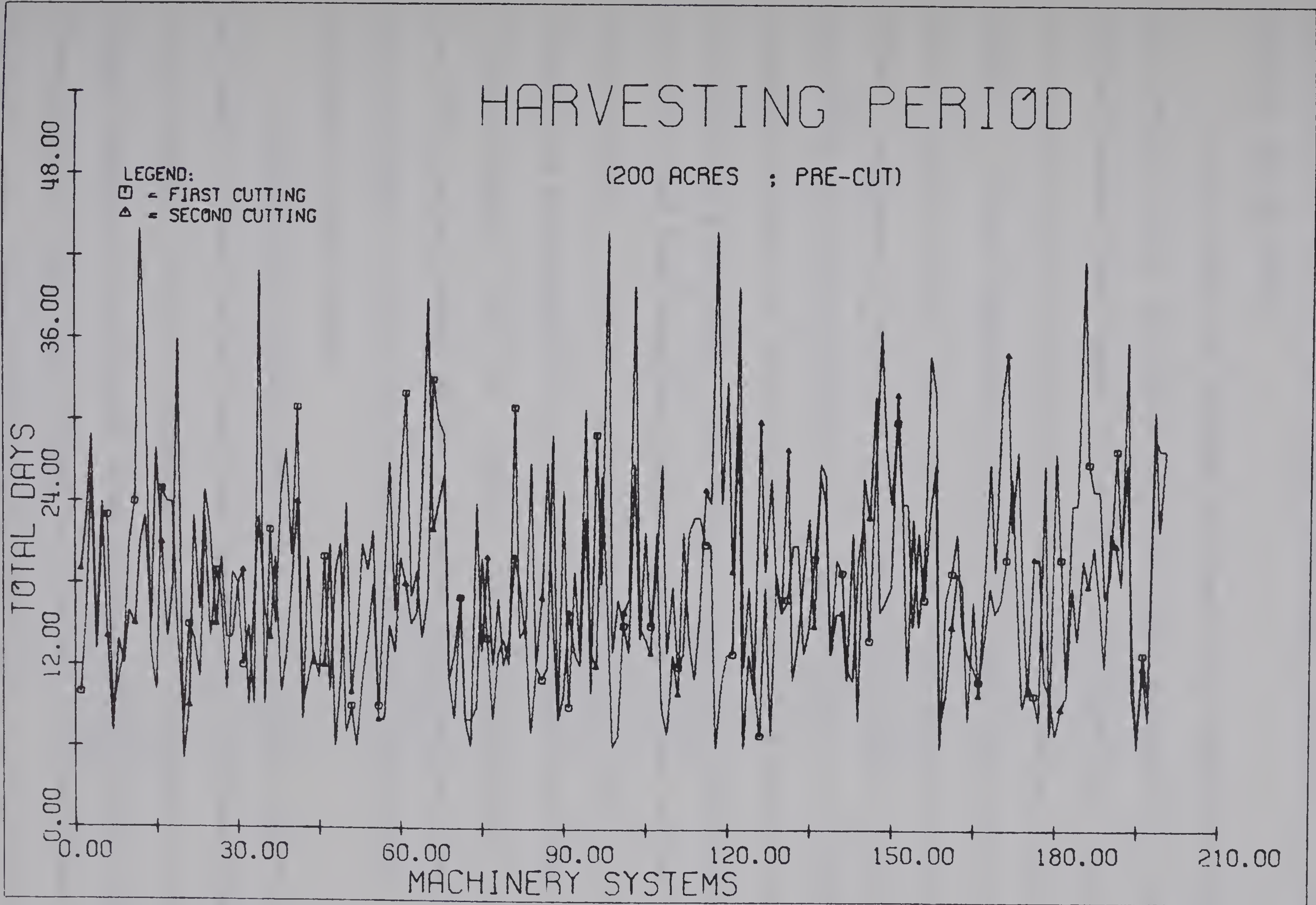


Figure 32. Duration of harvest for 200 acres -- pre-cut harvesting.

includes some field curing of the forage. Only in a very few of the simulated harvest seasons was the 44-day period inadequate to completely harvest the 200 acres.

As with direct-cut systems, cost per ton of digestible protein fed and cost per ton of dry matter fed serve almost equally well in ranking pre-cut systems (see figures 33 and 34). The variability in cost per ton of digestible protein fed was due primarily to the storage aspects of the system. A closer examination of the systems shows (see table K3 for the list of nodes) that the lower cost systems within a group utilized forage blowers as opposed to chain-&-flight conveyors, in spite of the favorable bias given to conveyor capacities (see section 7.1.5). The length and maximum inclination of the one conveyor used in the simulation precluded silos above a given height. The matching tower silos therefore tended to be shorter and less capacious, and consequently the cost per ton of dry matter fed rose. Cost per ton of digestible protein stored is both greater and more variable for pre-cut than for direct-cut systems (compare figures 13 and 33). However, the difference between cost per ton of dry matter stored and fed is greater for direct-cut than for pre-cut systems. Some of this greater difference is due to the additional storage losses.

Although total penalty costs for pre-cut systems (figure 31) do not seem to be much larger than those for direct-cut systems (figure 11) at the 200-acre level, the breakdowns do differ. In figure 35, the proper ranking of the different kinds of losses is not readily apparent. Pre-cut system field losses account for from one to three dollars per harvested acre; storage losses seem to cost roughly one half of those accruing to direct-cut systems (see figure 15). Maturity and weathering

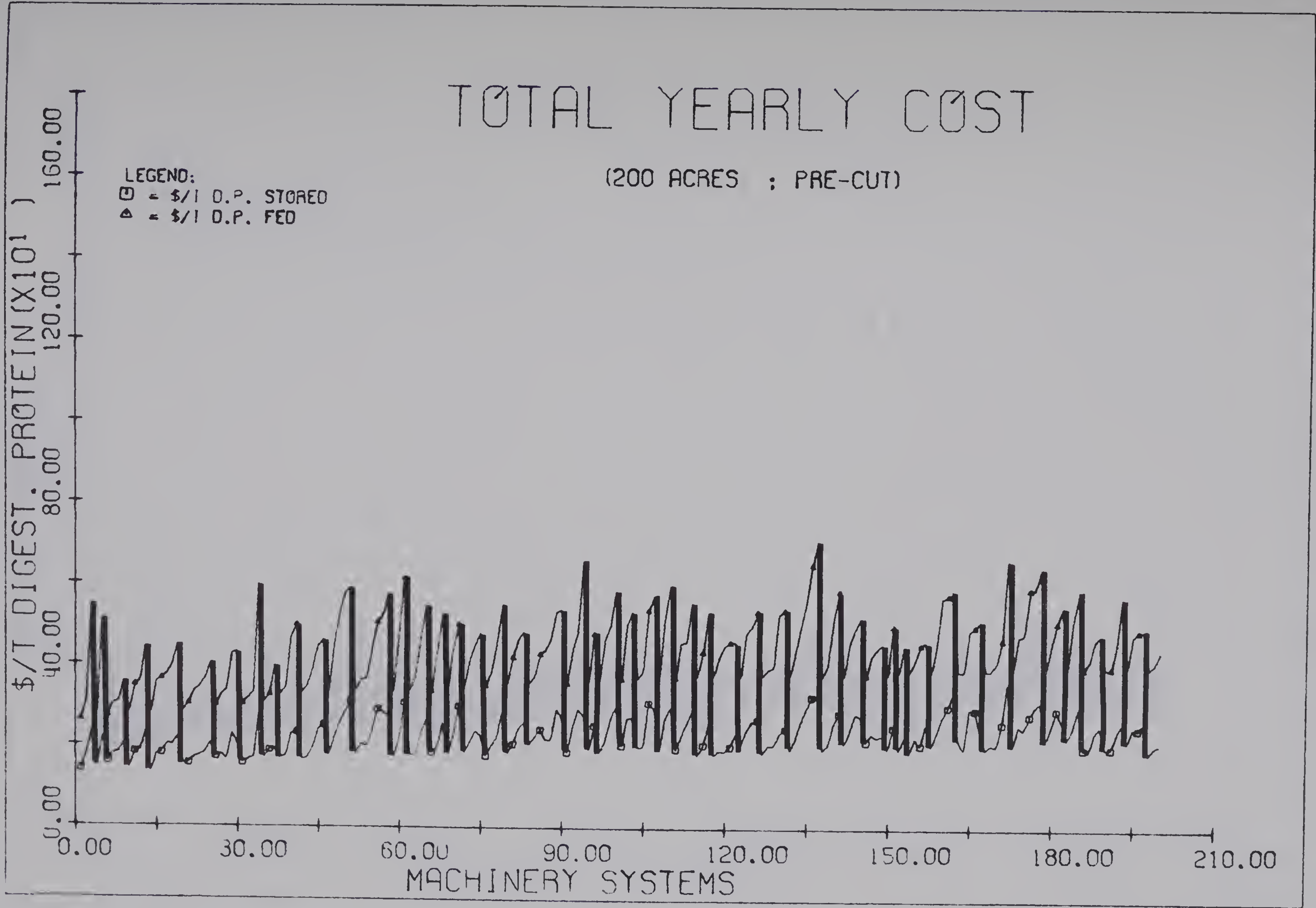


Figure 33. Cost per ton of digestible protein from 200 acres -- pre-cut harvesting.

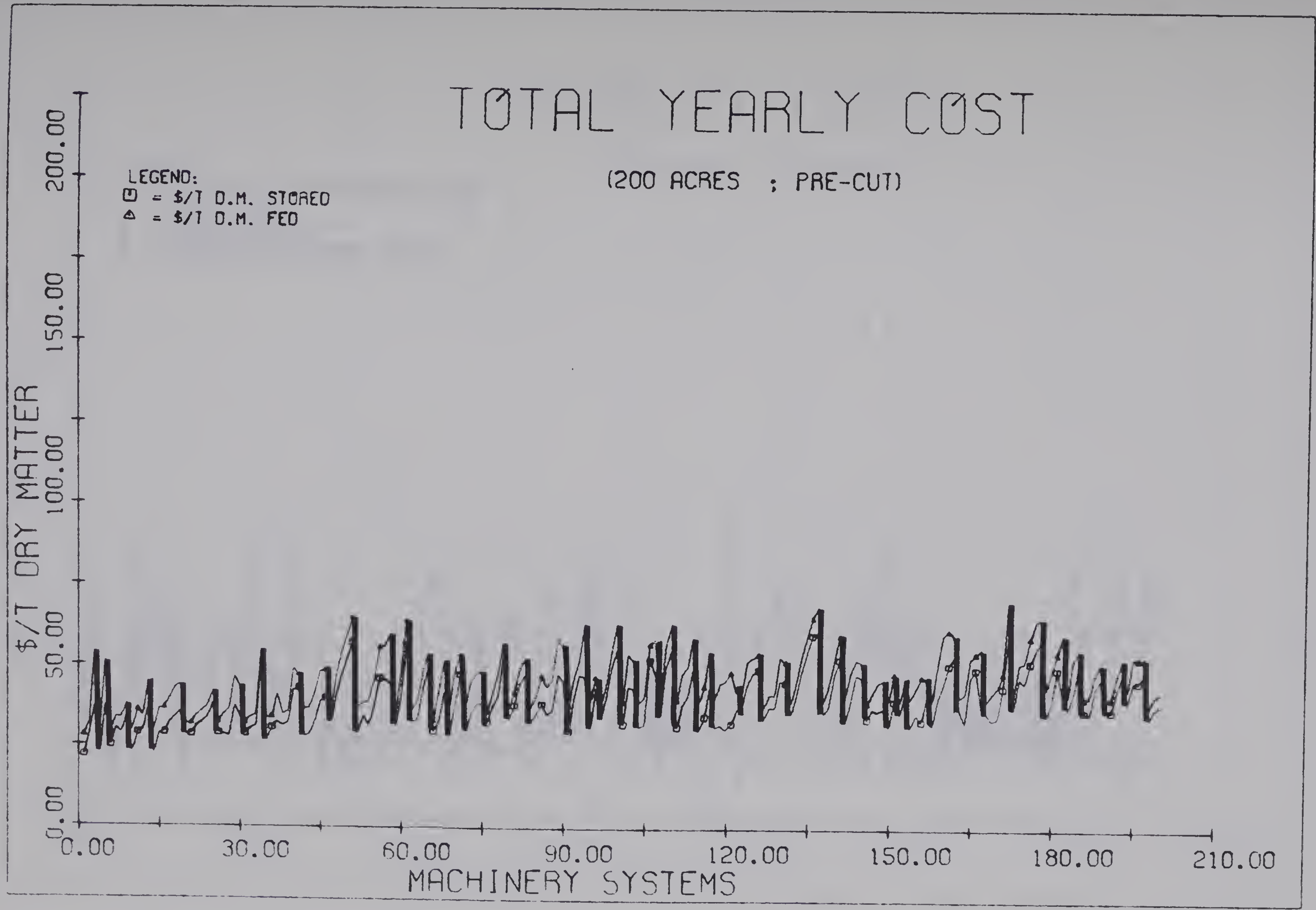


Figure 34. Cost per ton of dry matter from 200 acres -- pre-cut harvesting.

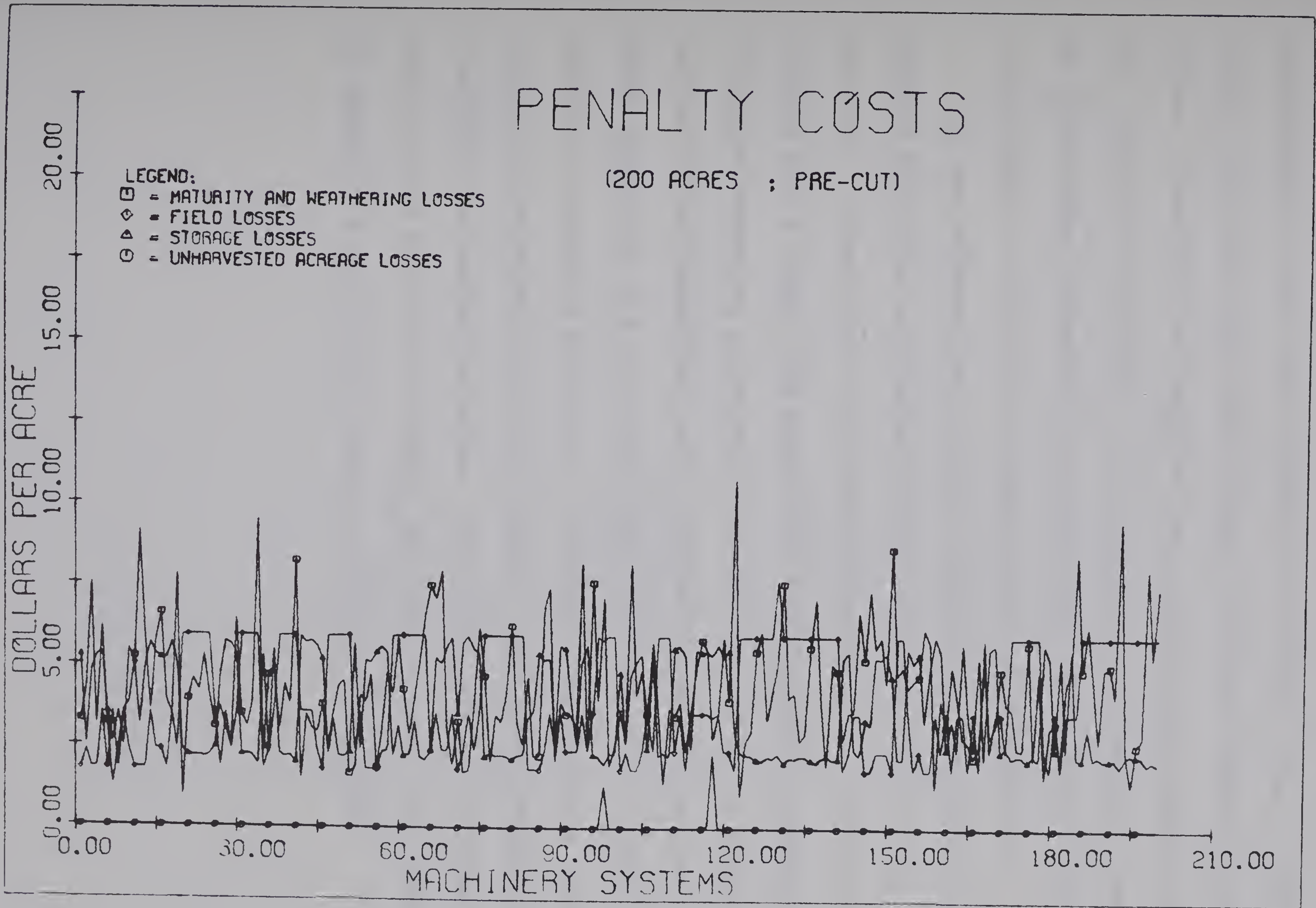


Figure 35. Penalty costs per acre for 200 acres -- pre-cut harvesting.

losses have increased over those of direct-cut systems. If an accurate means of predicting drying rates and dry matter losses from meteorological records were available for different types of harvesting systems, this loss figure would probably climb even higher for some systems. Even with the simplified and unsophisticated approach used in this simulation (see section 7.1.4 and Appendix H), maturity, weathering and field losses accounted for well over half of the total penalty cost in most years, or from five to eight dollars per harvested acre.

At the 300-acre level, little change in per acre costs could be observed other than a narrowing of cost variations within groups (see figure 36). Fixed costs still dominated the picture. The harvesting extended over a longer time period with more frequent occurrences of unfinished harvesting at the end of the 44-day period (see figure 27). Cost per ton of digestible protein (figure 38) and cost per ton of dry matter (figure 39) did not change appreciably except for a small reduction in standard deviation. As expected, penalty costs per acre (figure 40) increased only in the cases of unharvested acreage losses and of maturity and weathering losses. The latter tended to fluctuate even further up the scale than it had at the 200-acre level. The former did not appear as a cost in the ranking of alternative systems.

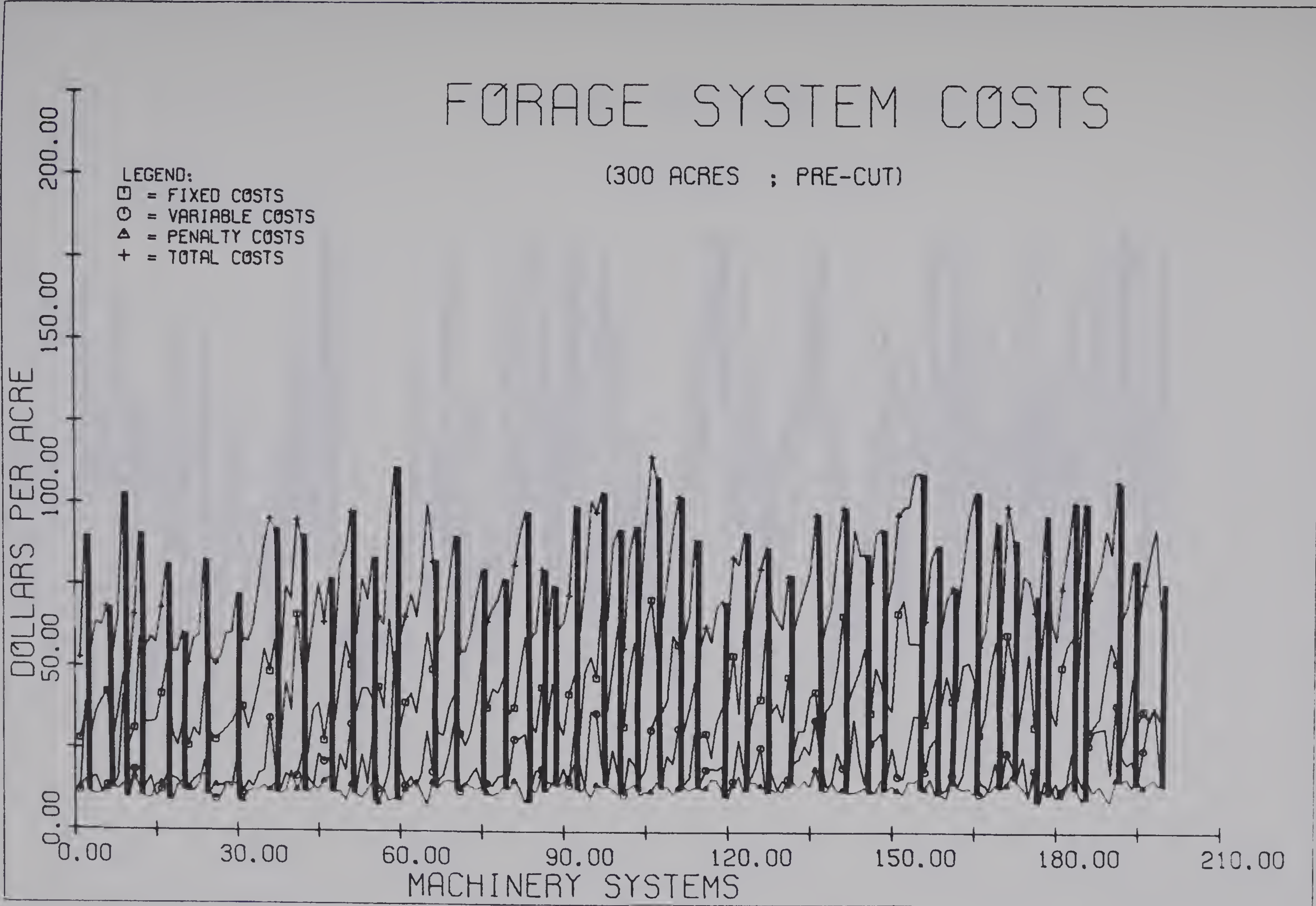


Figure 36. Forage system costs for 300 acres -- pre-cut harvesting.

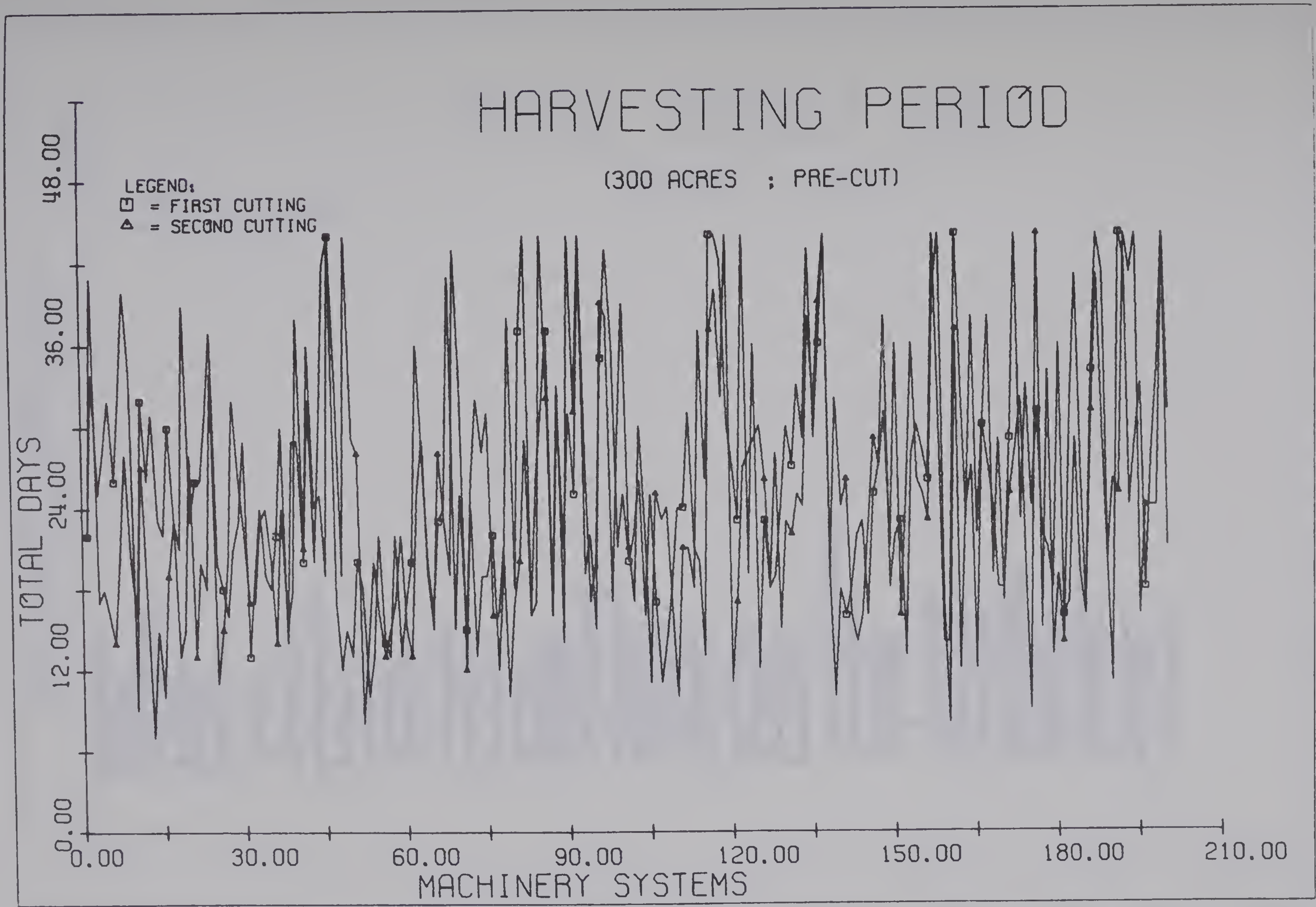


Figure 37. Duration of harvest for 300 acres -- pre-cut harvesting.

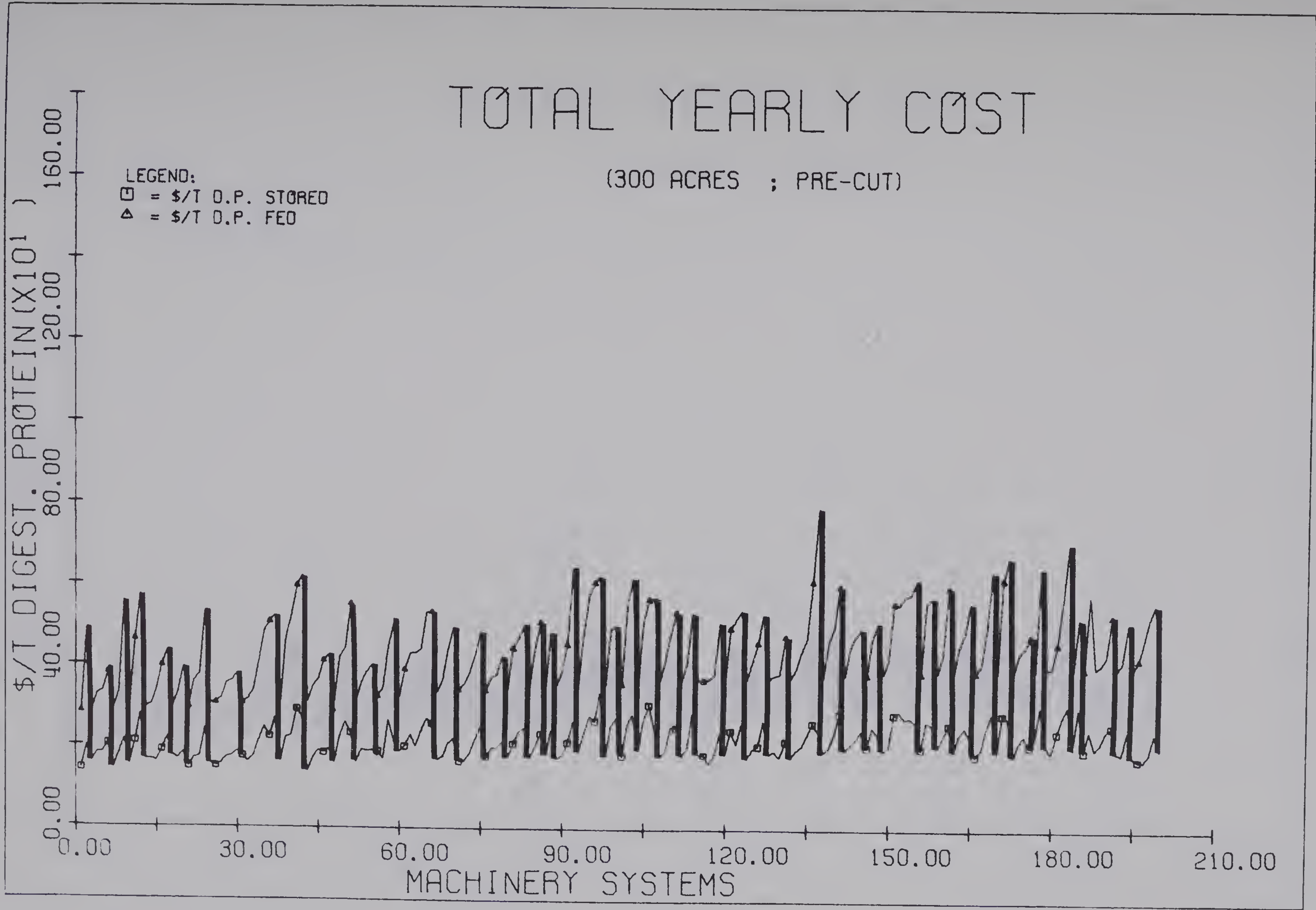


Figure 38. Cost per ton of digestible protein from 300 acres -- pre-cut harvesting.

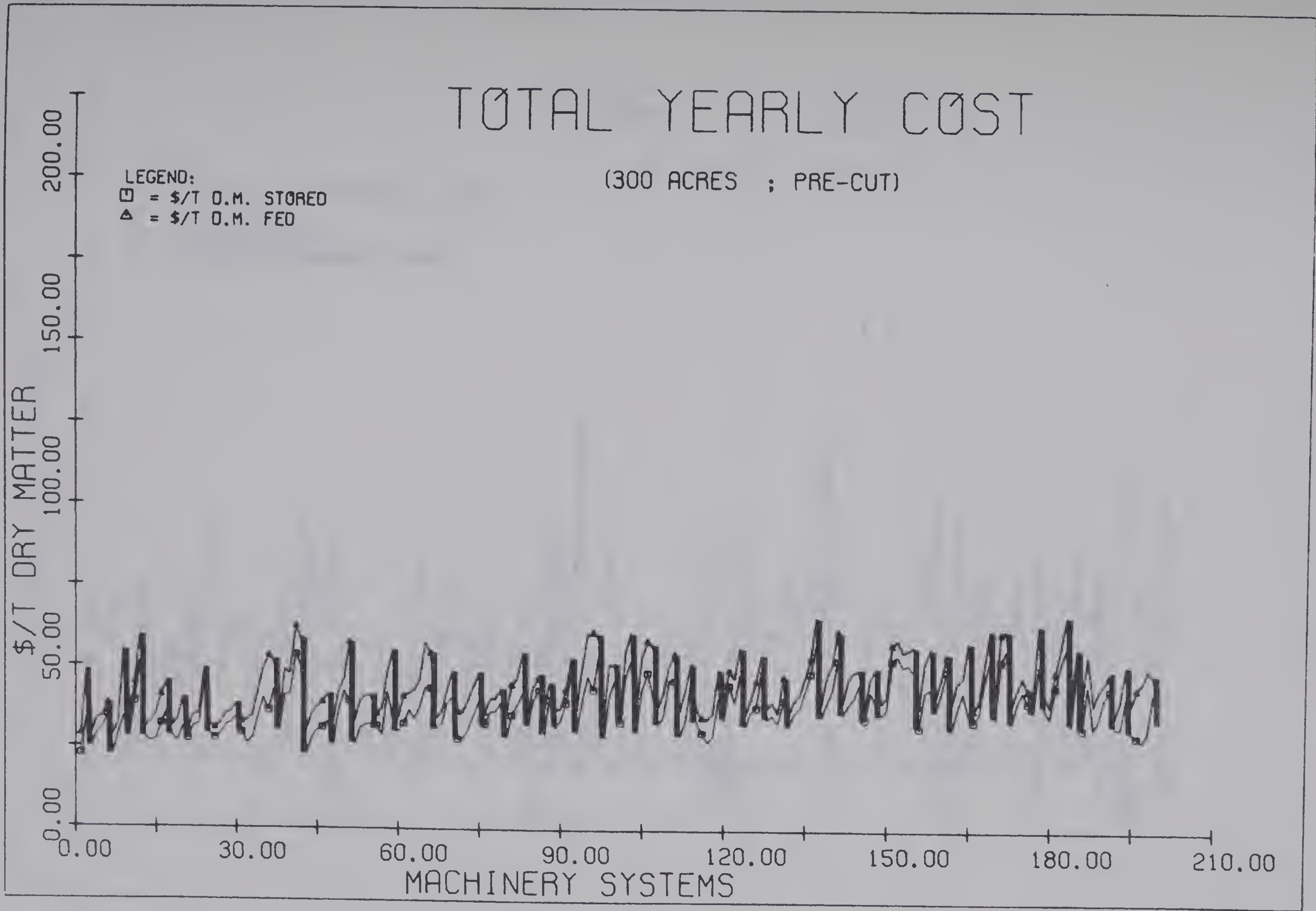


Figure 39. Cost per ton of dry matter from 300 acres -- pre-cut harvesting.

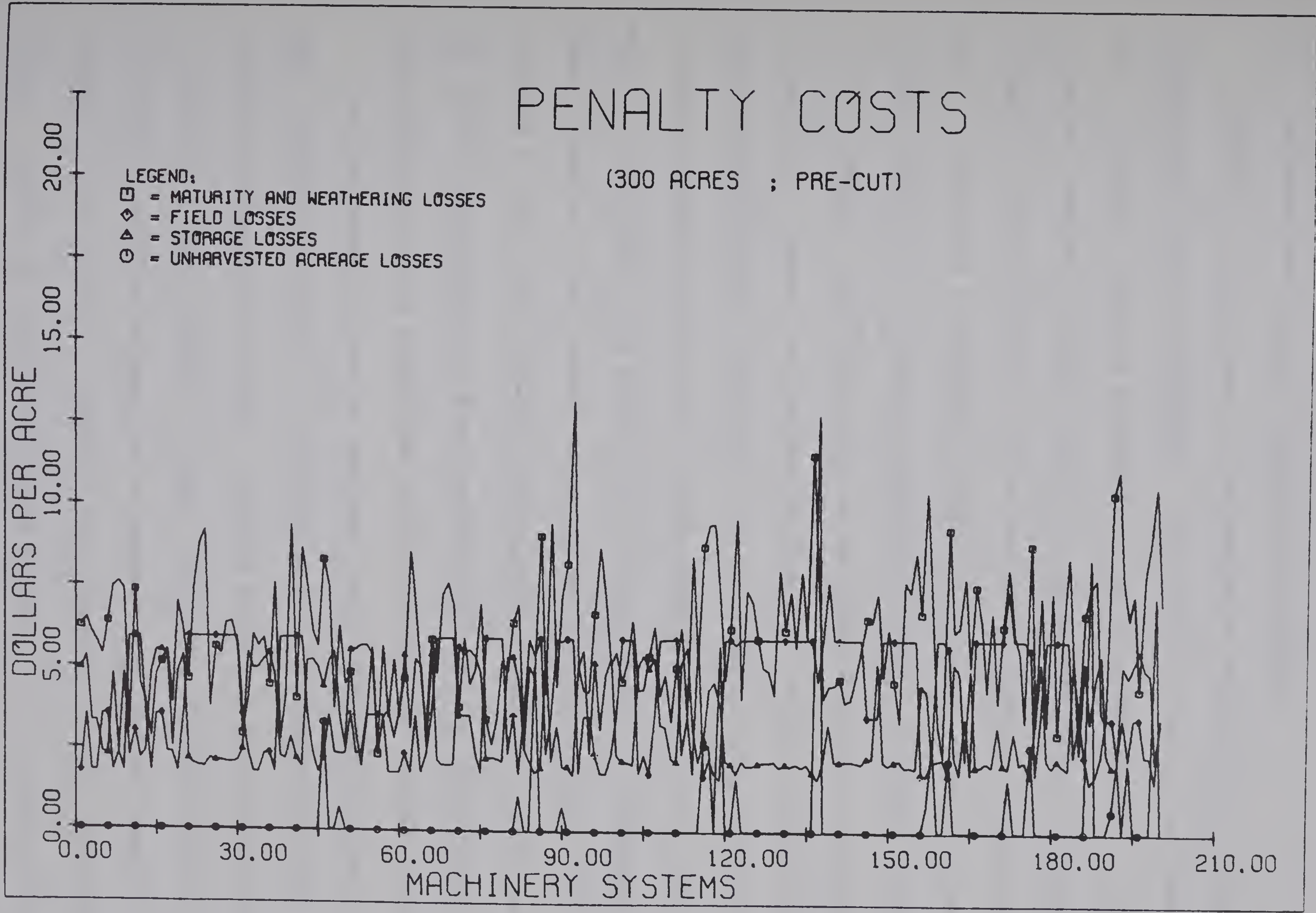


Figure 40. Penalty costs per acre for 300 acres -- pre-cut harvesting.

8. COMPARABLE MATHEMATICAL METHODS

8.1 Simulated Sampling and Separable Programming

Alternative approaches to the problem of determining an optimum forage system could be suggested. One involves a use of both Monte Carlo techniques and some extensions of LP - in that order. If adequate historical weather data are available, and if the effect of weather on forage cut and collected in a given manner is known, a simulation program might be developed to generate penalty vs capacity curves for each harvest period and at several probability levels. MacHardy (84) pointed out that machine fixed costs tend to be linear functions of machine size or capacity. However, by introducing special variables using piece-wise linear approximations, non-linear cost vs capacity curves can be utilized to gain increased accuracy and to approximate step functions that often exist. Conceivably, the above sets of curves could be introduced to the same LP matrix. Then product terms, as outlined by MacHardy (83), could be added to allow for cost-time interactions. Other equations could link the above relationships to time, acreage and capital restrictions. Separable programming algorithms would solve for the optimum system.

One advantage of such an approach lies in the shorter computation time. Because the matrix is manipulated in an iterative way that successively improves the basic feasible solution, an optimal solution is found in a finite number of steps. However, one disadvantage is the preliminary calculation required to generate the cost vs capacity curves. Another is the amount of computer storage needed to store the mammoth matrix. One way of circumventing this problem is to analyze the matrix in successive steps, i.e. a few types of systems at a time. Where alternative enterprises compete for available resources, the

decomposition principle as described by Dantzig (34) may have to be applied. A third disadvantage is the possibility that the separable program may select a local optimum as the global optimum. Convexities in concave functions may have to be bypassed by re-running the program with different initial conditions.

Sensitivity analyses are often of more importance than the optimal solution itself, since much of the information going into the program may contain error or uncertainty. New penalty vs capacity data could give the new probability and cost of completing harvest. If the computer package provides a possible post-optimal analysis, the effect of changing limits or the effect of trade-offs can be ascertained for resource variables.

8.2 SPNA and Monte Carlo Techniques

A second possibility is a Monte Carlo simulation of a SPNA network. The first stage would be to redesign the network of forage handling alternatives to fit Preston's (99) SPNA routine. Since some arc costs tend to follow a random distribution, instead of an arc being on or off the critical (shortest) path, it has a probability of being on the critical path.

According to Hillier and Lieberman (60), PERT-type solution methods incorporate distributions, but rely more on means and estimated variances of arc values than on distribution structures. The Monte Carlo approach does depend on distribution shapes but adds flexibility in that any distribution or mix of distributions can be used for arc variables. Van Slyke (113) applied Monte Carlo simulation to PERT networks, and only a slight modification of his approach led to the series of steps proposed as follows:

(1) Establish the objective function of the SPNA network.

(2) Decide on the number of trials, N_x, for sampling (intuition and experience influencing this subjective decision).

(3) For each of the trials, set the levels of any stochastic variables via random number generators before solving for the shortest path.

(4) Determine sample mean, μ_x, and variance σ_x^2, of the random variable ,X, corresponding to minimum cost.

(5) Calculate, for each arc, the per cent of the time it was critical, P_x.

(6) Indicate the desired probability that the estimate of the true variance is within a specified percentage of the correct variance. Using established statistical techniques (118), determine the number of trials required, N_σ.

(7) Given P_x, the observed probability that a given arc is on the critical path, indicate the desired probability that P_x is within a specified percentage of P. Using established statistical techniques (118),find the number of trials required, N_p.

(8) If N_σ or N_p is greater than N_x, rerun the program.

The output of such a program should give the system-cost density function, mean value and variance, and the 'criticality index' for each arc in the network. Such an index would provide one means of evaluating the sensitivity of the optimal solution. Additional sensitivity analyses might consist of reruns with new distributions for certain variables or altered probability levels.

The prime difficulty in using such an approach is the computer time

requirement which is almost an exponential function of the number of arcs in the network. One solution might be an application of Dantzig's (34) decomposition principle. Another might be to take a relatively small initial sample and then eliminate all arcs that were never critical. Knowing the initial sample size and the probability of an arc being critical, the probability of making an error in eliminating a critical arc can be calculated. Alternatively, one could keep all arcs in the program but weight the frequency of selecting any arc inversely to its estimated importance.

8.3 Dynamic Programming and Simulated Sampling.

A third approach involves dynamic programming. The forage handling system of alternatives could be thought of as a dynamic multistage problem requiring a sequence of decisions. "Bellman's principle of optimality" referred to by Dantzig (34) emphasizes the application of the inductive principle to such problems. An optimal policy has the property that whatever the initial state and the initial condition are, the remaining decisions must constitute an optimal policy with respect to the state resulting from the first decision. Hillier and Lieberman (60) discussed the characteristic features of dynamic programming problems. These can be listed as:

(1) The problem is divisible into stages, each stage requiring a policy decision.

(2) Each stage has a number of states associated with it, either finite or infinite.

(3) The effect of the policy decision at each stage is to transform the current stage into a state associated with the next stage (possibly according to a probability distribution).

(4) Given the current state, an optimal policy for the remaining stages is independent of the policy adopted in previous stages.

(5) The solution procedure begins by determining the optimal policy for each state of the last stage.

(6) A recursive relationship is available which identifies the optimal policy for each state with n stages remaining, given the optimal policy for each state with (n-1) stages remaining.

(7) Using this recursive relationship, the solution procedure moves backward through each stage - finding the optimal policy for each state of that stage - until it finds the optimal policy when starting at the initial stage.

One could begin by expanding the existing network to ensure that the exiting arc chosen for any one node is independent of previously selected arcs. The network could then be rearranged into columns of nodes, each column corresponding to a stage, and each node corresponding to a state. Flow from a node can only go to a node in the adjacent column on the right, the policy decision to dictate which node. The number assigned as the "distance" between connected nodes can be interpreted as the cost contribution made to the system by going from one 'state' to another. The objective would be to find the shortest route through the network, and thus the optimal system.

If the initial and terminal nodes of the modified network were the same as those used in the existing network (see figures 5, 6, 21 to 24),

the objective function may be minimum cost per unit of protein fed, or some other objective compatible with managerial goals. After specifying the objective function, the solution procedure can begin by setting definite values for the required amount of protein and the desired cost per unit of protein - the optimal policy for the last stage.

This problem is atypical of dynamic programming problems in that one manageable recursive relationship cannot be constructed. As the solution procedure moves backward through each stage, finding the optimal policy for each state of that stage involves determination of one cost figure for each arc, which in turn may require an evaluation of equations, a testing of resource availability, and simulated sampling. It is conceptually possible to attach a specified confidence limit to a cost value assigned to an arc connecting two nodes.

A dynamic programming approach obviates the necessity of evaluating an almost infinite number of possibilities resulting from a large, diverging network. This approach tends to change a problem in n variables to n problems in one variable. On occasion, dynamic programming permits a more analytic analysis for certain arcs, e.g. calculus versus the Monte Carlo technique, which reduces computation requirements. Nevertheless, programming effort, computer storage space and computation time provide potential limitations to use of this dynamic programming approach. Sensitivity analysis would consist of successive program reruns with different 'optimal policies' for the last stage, altered resource availabilities and/or redefined confidence limits.

9. CONCLUSIONS

Of the systems simulated at two acreage levels, high-moisture silage systems outperformed the other three - wilted silage, haylage and dehydrated forage to some degree. Within the systems studied, considerable cost overlap existed. The minimum-cost systems for high moisture silage, wilted silage and haylage exhibited a cost range in common - at least under Edmonton weather and price conditions. Wilted silage and haylage systems compared favorably on a cost basis, but were more sensitive to changes in system parameters than were high-moisture silage systems. Cost per unit of production for any particular system does not alter appreciably between 200 and 300 acres. Where a silage-type end product is concerned, the break-even point between optimal and sub-optimal systems may occur at lower acreage levels.

The range of forage making costs indicated by the analysis suggest that actual interest and depreciation rates used in establishing custom rates must be considerably lower than those used in this study. Indicated forage making costs were generally higher than present custom rates.

The suitability of the GPSS programs in generating and costing alternate forage handling systems is questionable. The GPSS approach is an awkward one that monopolizes computer storage and time unless the problem is subdivided into several stages. If the network can be successfully split up into many small sections, the system possibilities within these sections simulated in separate GPSS programs, and the results pooled to be later analyzed with another program, the GPSS approach provides a workable way of conducting a cost-benefit simulation of forage handling. At best, computer time and storage requirements are

extensive.

An examination of other simulation methods however, suggests that regardless of the mathematical method used to compare alternate forage handling systems, large programs seem unavoidable. The present diversity of equipment and techniques is still on the increase. Any attempt to systematically analyze this expanding network of possibilities appears destined for a piecemeal approach compatible with available computer hardware. Simulation of weather-dependent variables at some point in the analysis seems unavoidable if the overlapping of system costs is to be recognized.

Definite data gaps exist in present engineering, nutritional and agrometeorological data on forage handling. Quantitative coefficients are often needed where only qualitative assessments have been made. Mechanical properties such as angle of repose, angle of internal friction, coefficients of friction, heat of respiration and thermal diffusivity, to name some, are frequently unavailable when calculating the engineering requirements for handling the forage as it moves from field to feedbunk. Even a range of possible values would be of more use to systems analysts than none at all. The nutritional value of forage cut and collected in a specified manner and subsequently receiving a known amount of weathering is too often unknown. The third data gap is indicated as a major one by the analysis conducted in this thesis. Drying and wetting rates of cut forage that have been measured in one area under one weather régime are not necessarily directly transferrable to another area subject to different weather patterns.

In general, it is felt however, that attempts at mathematical analysis will assist in pointing out areas for research, and that the data gap will consequently diminish.

10. BIBLIOGRAPHY

1. Ackoff, Russell L. (ed.) Progress in Operations Research, Vol. I, Publications in Operations Research No. 5. New York: John Wiley & Sons, Inc., 1961.

2. Anderson, A.W. "A Study of the Application of Linear Programming and the Associated Technique of Decomposition for Use on Farm Management Problems in Alberta". Unpublished M.Sc. Thesis, Department of Agricultural Engineering, University of Alberta, December, 1965.

3. Baier, W. and Robertson, Geo. W. "Estimation of Latent Evaporation From Simple Weather Observations", Canadian Journal of Plant Science, XLV (3), 1965, 276-284.

4. Baier, W. and Russelo, D.A. "A Computer Program for estimating risks of irrigation requirements from climatic data". Technical Bulletin 59, Agrometeorology Section, Plant Research Institute. Ottawa: Canada Department of Agriculture, 1968.

5. Bainer, Roy, Kepner, R.A. and Barger, E.L. Principles of Farm Machinery. New York: John Wiley & Sons, Inc., 1955.

6. Baldwin, A.L. "Some Aspects of Agricultural Project Planning and Management Using Network Analysis", Journal and Proceedings of the Institution of Agricultural Engineers, XXIV (4), 1969, 163-172.

7. Bargen, Kenneth von. "Systems Analysis in Hay Harvesting", Transactions of the ASAE, IX (6), 1966, 768-770 ff.

8. Barger, E.L. et al. Tractors and Their Power Units. 2nd ed. New York: John Wiley & Sons, Inc., 1963.

9. Barrington, G.P. and Bruhn, H.D. "Effect of Various Mechanical Forage Harvesting Devices on Field Curing Rates and Relative Harvesting Losses". Paper No. 69-144 for presentation at the 1969 Annual Meeting, American Society of Agricultural Engineers, Purdue University, W. Lafayette, Indiana, June 22-25.

10. Beauvois, Fievet, Grillot et Guillet. Les chaînes de récolte des fourrages. Etude Technico-économique des chantiers. Paris: Bureau Commun du Machinisme Agricole, 1968.

11. Bellinger, P.L. and McColly, H.F. "Energy Requirements for Forming Hay Pellets", Agricultural Engineering, XLII (4), 1961, 180-181 and (5), 1961, 244-247 ff.

12. Bohstedt, G. "Nutritional Values of Hay and Silage as Affected by Harvesting, Processing and Storage", Agricultural Engineering, XXV (9), 1944, 337-340.

13. Bonder, Seth. "Developing Planning Procedures for Armored-Weapons Systems", Transactions of the ASAE, X (3), 1967, 296-302.

14. Bonnicksen, L.W. "Simulators for Farmstead Systems Analysis", Transactions of the ASAE, X (6), 1967, 806-807 ff.

15. Bowren, K.E., Cooke, D.A. and Downey, R.K. "Yield of Dry Matter and Nitrogen From Tops and Roots of Sweetclover, Alfalfa, and Red Clover at Five Stages of Growth", Canadian Journal of Plant Science, IL (1), 1969, 61-68.

16. Boyd, M.W. and Larsen, W.E. "Time and Motion Studies of Hay Harvesting Systems". Paper for presentation at the 1969 Annual Meeting of the Pacific Northwest Section, American Society of Agricultural Engineers, Vancouver, British Columbia, October 1-3.

17. Brooker, D.B. "Mathematical Model of the Psychrometric Chart", Transactions of the ASAE, X (4), 1967, 558-560 ff.

18. Brooks, C.E.P. and Carruthers, N. Handbook of Statistical Methods in Meteorology. London: Her Majesty's Stationery Office, 1955.

19. Bruck, I.G.M. and Elderen, E. van. "Field Drying of Hay and Wheat", Journal of Agricultural Engineering Research, XIV (2), 1969, 105-116.

20. Canada. Department of Agriculture. Report of the Workplanning Conference on the Harvesting, Storage and Utilization of Hay and Silage Crops, January 30-31, 1970. Prepared by the Research Branch. Ottawa, 1970.

21. Canada. Department of National Revenue, Taxation. "1969 Farmer's & Fisherman's Tax Guide". Ottawa: Department of National Revenue, Taxation.

22. Canada. Dominion Bureau of Statistics. 1966 Census of Canada, Vol. V, Agriculture, Catalogue No. 96-610. Ottawa, 1968.

23. __________ Canadian Agriculture in the Seventies. Report of the Federal Task Force on Agriculture. Ottawa: Queen's Printer, 1969.

24. __________ "Chain and Belt Conveyors", Section 2.1, Agricultural Materials Handling Manual. Ottawa: The Queen's Printer, 1962.

25. Chestnut, Harold. Systems Engineering Methods. New York: John Wiley & Sons, Inc., 1967.

26. Chestnut, Harold. Systems Engineering Tools. New York; John Wiley & Sons, Inc., 1965.

27. Churchman, C. West, Ackoff, Russel L., and Arnoff, E. Leonard. Introduction to Operations Research. New York: John Wiley & Sons, Inc., 1957.

28. Coales, J.F. "An Outline of Systems Engineering", Journal and Proceedings of the Institution of Agricultural Engineers, XXIV (1), 1969, 13-24.

29. ____________ "Conference Proceedings: Computers and Farm Machinery Management", Sherman House, Chicago, Ill., December 9-10, 1968. ASAE Publication PROC-468. St. Joseph, Michigan: American Society of Agricultural Engineers.

30. Coupland, G.A. and Halyk, R.M. "Input Data for a Network Analysis of Forage Harvesting Systems". Paper for Presentation at the 1969 Annual Meeting, Canadian Society of Agricultural Engineering, University of Saskatchewan, Saskatoon, August 24-27.

31. Curley, R.G., Dobie, J.B. and Parsons, P.S. "Methods and Costs For Feeding Alfalfa Cubes to Beef". Paper No. 70-315 for presentation at the 1970 Annual Meeting, American Society of Agricultural Engineers, Minneapolis, Minnesota, July 7-10.

32. ____________ "Custom Rates For Farm Machinery", Farm Notes. Assembled and Released by Information Branch, Alberta Department of Agriculture, Edmonton. Wednesday, May 7, 1969.

33. ____________ "Cut Hay in Early June", The Grain Grower. May 1966, Section p. 120.125.

34. Dantzig, George B. Linear Programming and Extensions. New Jersey: Princeton University Press, 1963.

35. Day, C. Leroy. "Effects of Conditioning and Other Factors on Resistance of Hay to Air Flow", Transactions of the ASAE, VI (3), 1963, 199-201.

36. Decker, Martin. "Unloading Silos Mechanically", Agricultural Engineering, XLI (6), 1960, 378-380.

37. Dent, J.B. and Casey, H. Linear Programming and Animal Nutrition. Toronto: J.B. Lippincott Company, 1967.

38. Devine, E.S. and Wright, W. "An Investigation into Bale Handling Techniques During Harvest", Journal of Agricultural Engineering Research. X (1), 1965, 44-59.

39. Dilke, N.W. "Silage Making with Forage Harvesters: Methods and Outputs", Journal of Agricultural Engineering Research, III (3), 1958, 235-248.

40. Dobie, John B. "Mechanical Feeding of Livestock", Agricultural Engineering, XXXVI (7), 1955, 458-461 ff.

41. Dobie, J.B. and Curley, R.G. "Material Handling System for Stationary Hay Cubing". Paper No. 70-316 for presentation at the 1970 Annual Meeting, American Society of Agricultural Engineers, Minneapolis, Minnesota, July 7-10.

42. Donaldson, G.F. "Allowing for Weather Risk in Assessing Harvest Machine Capacity", American Journal of Agricultural Economics, L (1), 1968, 24-40.

43. Donaldson, G.F. and Webster, J.P.G. "A Simulation Approach to the Selection and Combination of Farm Enterprises", The Farm Economist, XI (6), 1967, 219-229

44. Dudar, Terry N. "Hay Conditioning in Manitoba". Unpublished B.Sc. Thesis, Department of Agricultural Engineering, University of Saskatchewan, April, 1965.

45. Duyne, D.A. van and Kjelgaard, W.L. "Air-Flow Resistance of Baled Alfalfa and Clover Hay", Transactions of the ASAE, VII (3) 1964, 267-270.

46. ______________ "Engineering Data", Section 7.2, Agricultural Materials Handling Manual. Ottawa: The Queen's Printer, 1964.

47. Esmay, M.L. and Brooker, D.B. "Lateral Pressures in Horizontal Silos", Agricultural Engineering, XXXVI (10), 1955, 651.

48. ______________ "Farm Machinery Costs and Use", ASAE Data: ASAE D230.1. American Society of Agricultural Engineering Yearbook 1969. St. Joseph, Michigan: ASAE, 1969, 278-283.

49. ______________ "Forage Highlights". Proceedings of the Second Research-Industry Conference, Chicago, Ill., February 4-5, 1969. State College, Pennsylvania.

50. Ford, R.M. and Bilanski, W.K. "Thermal Diffisuvity of Alfalfa Stems", Transactions of the ASAE, XII (2), 1969, 249-251.

51. Fulkerson, R.S., Mowat, D.M., Tossell, W.E. and Winch, J.E. "Yield of Dry Matter, IN VITRO Digestible Dry Matter and Crude Protein of Forages", Canadian Journal of Plant Science, XLVII (6), 1967, 683-690.

52. ______________ "General Purpose Simulation System/360 User's Manual". IBM Application Program No. H 20-0326-2, 1968.

53. Goss, J.R., Kepner, R.A. and Jones, L.G. "Hay Harvesting with Self-Propelled Windrower Compared With Mowing and Raking", Transactions of the ASAE, VII (4), 1964, 357-361.

54. Greer, James D., Henderson, Philip A. and Schepler, Lloyd A. "Costs of Owning and Operating Farm Machinery". Lincoln: Department of Agricultural Economics, University of Nebraska, 1969.

55. Hall, Carl W. Drying Farm Crops. Reynoldsburg, Ohio: Agricultural Consulting Associates, Inc., 1957.

56. Hall, Carl W. "Theoretical Considerations in Materials Handling Systems", Agricultural Engineering, XXXIX (9), 1958, 527.

57. Hall, Glenn E. "Flail Conditioning of Alfalfa and Its Effect on Field Losses and Drying Rates", Transactions of the ASAE, VII (4), 1964, 435-438.

58. Harrison, C.M. (ed.) Forage: Economics - Quality, A.S.A. Special Publication Number 13. Madison, Wisconsin: American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, 1968.

59. Heinrichs, D.H., Troelsen, J.E. and Warder, F.G. "Variation of Chemical Constituents and Morphological Characters Within and Between Alfalfa Populations", Canadian Journal of Plant Science, IL (3), 1969, 293-305.

60. Hillier, F.S. and Lieberman, G.J. Introduction to Operations Research. San Francisco, California: Holden-Day Inc., 1967.

61. Hundtoft, E.B. "Handling Hay Crops - From Standing Crop to Windrow", Agricultural Engineering Extension Bulletin 364. Ithaca, New York: Cornell University.

62. Hundtoft, E.B. and Guest, R.W. "Handling Hay Crops - From Windrow to Feed Bunk", Agricultural Engineering Extension Bulletin 365. Ithaca, New York: Cornell University.

63. Hertz, David B. and Eddison, Roger T. (eds.) Progress in Operations Research, Vol. II, Publications in Operations Research No. 9. New York: John Wiley & Sons, Inc., 1964.

64. Horne, B.S. and Kjelgaard, W.L. "Field Evaluations of Self-Propelled Windrowers as Hay Making Tools". Paper No. 62-148 for presentation at the 1962 Annual Meeting, American Society of Agricultural Engineering, Washington, D.C., June 17-20.

65. Hunt, Donnell R. "A Systems Approach to Farm Machinery Selection", Journal and Proceedings of the Institution of Agricultural Engineers, XXIV (1), 1969, 25-30.

66. Ingalls, J.R. Jr. "Influence of Harvest Date Upon The Nutritive Value of Forages". An unpublished M.S. Thesis, University of Vermont, June, 1960.

67. Jeffers, J.P.W. "A Mathematical Model for the Selection of Haying Machinery". Unpublished M.Sc. Thesis, Department of Agricultural Engineering, University of British Columbia, 1966.

68. Jordan, K.A., Takakura, T., Buffington, D.E. and Boyd, L.L. "Weather Models for Plants and Animals". Paper No. 69-917 for presentation at the 1969 Winter Meeting, American Society of Agricultural Engineers, St. Paul, Minnesota, December 9-12.

69. Kampen, Ir. J.H. van. Optimizing Harvesting Operations on a Large-Scale Grain Farm, Van Zee Totland 46. Rijkadienst voor de IJsselmeerpolders Zwolle, 1969.

70. Keller, P. "Labour Requirement in Silage Making". Paper presented at the XIV International Congress of Scientific Management of Farm Work, CIOSTA/IRL in Helsinki, Finland, 1968.

71. Kemp, J.G., Misener, G.C. and Roach, W.S. "Empirical Formulae for Field Drying Hay". Paper for presentation at the 1970 Annual Meeting North Atlantic Region, American Society of Agricultural Engineers, Newark, Delaware, August 16-18.

72. Kepner, R.A. et al. "Evaluation of Hay Conditioning Effects", Agricultural Engineering, XLI (5), 1960, 299-304.

73. Kershner, R.B. "A Survey of Systems Engineering Tools and Techniques". Operations Research and Systems Engineering. ed. C.D. Flagle, W.H. Huggins, and R.H. Roy. Baltimore: The John Hopkins Press, 1960.

74. Kjelgaard, William L. "Flail Mower - Conditioners: Their Place in Forage Harvest", Agricultural Engineering, XLVII (4), 1966, 202.

75. Kurtz, P.J. and Bilanski, W.K. "Machine Treatments on Field Drying Hay", Canadian Agricultural Engineering, IX (2), 1967, 113-116.

76. Larsen, William E. Time and Motion Studies, Hay Harvesting Operations 1969. Material sent to Prof. T.A. Preston, Agricultural Engineering Department, University of Alberta, Edmonton, dated November 13, 1969.

77. Link, David A. "Activity Network Techniques Applied to a Farm Machinery Selection Problem", Transactions of the ASAE, X (3), 1967, 310-317.

78. Link, D.A. and Bockhop, C.W. "Mathematical Approach to Farm Machinery Scheduling", Transactions of the ASAE, VII (1), 1964, 8-13 ff.

79. List, Robert J. Smithsonian Meteorological Tables. 6th ed. revised. Washington, D.C.: Smithsonian Institution Press, 1949.

80. Lorenzen, Robert T. "Queuing Techniques in Designing and Operating Livestock Production Facilities", Transactions of the ASAE, X (4), 1967, 519-522.

81. MacHardy, F.V. "A Method for Sizing Farm Machines for Weather Dependent Operations", Canadian Agricultural Engineering, VIII (1), 1966, 26-28.

82. MacHardy, F.V. "An Investigation of the Application of Programming Techniques to Farm Management Problems". Unpublished Ph.D. Thesis, Faculty of Science, University of Edinburgh, 1964.

83. MacHardy, F.V. "Product Terms in Mathematical Programming". Canadian Agricultural Engineering, X (2), 1968, 51 ff.

84. MacHardy, F.V. "Programming for Minimum-Cost Machinery Combinations", Canadian Agricultural Engineering, VIII (1), 1966, 22-25.

85. Maish, L.J., Cuykendall, C.H. and Hasbargen, P.R. Economic Comparisons of Hay Harvesting, Storing and Feeding Systems for Beef Cow Herds, Economic Study Report S69-5. Department of Agricultural Economics, University of Minnesota. St. Paul, October, 1969.

86. ____________ "Mathematical Programming System/360 (360A-CO-14X) Linear and Separable Programming - User's Manual". IBM Application Program No. H 20-0476-0, 1967.

87. Meyer, S.F., Frisby, J.C. and Martz, F.A. "A Comparison of Hay Handling Systems". Paper No. MC-69-301 for presentation at the 1969 Mid-Central Region Meeting, American Society of Agricultural Engineers, St. Joseph, Missouri, March 28-29.

88. Millier, W.F. and Rehkugler, G.E. "A Simulation - The Effect of Harvest Starting Date, Harvesting Date and Weather on the Value of Forage for Dairy Cows". Paper No. 70-127 for presentation at the 1970 Annual Meeting, American Society of Agricultural Engineers, Minneapolis, Minnesota, July 7-10.

89. Moggach, G.S. "A Systems Approach to Managing Forage Harvesting Equipment". Paper No. 70-147 for presentation at the 1970 Annual Meeting, American Society of Agricultural Engineers, Minneapolis, Minnesota, July 7-10.

90. Morrison, Frank B. Feeds and Feeding. 22nd ed. Ithaca, N.Y.: The Morrison Publishing Co., 1949.

91. Nadler, Gerald. Work Systems Design: The IDEALS Concept. Homewood, Illinois: Richard D. Irwin, Inc., 1967.

92. National Research Council. Nutrient Requirements of Domestic Animals, Number IV Nutrient Requirements of Beef Cattle (rev. ed.). Publication 1137. Washington, D.C.: National Academy of Sciences - National Research Council, 1963.

93. Neubauer, L.W. and Walker, H.B. Farm Building Design. Englewood Cliffs, N.W.: Prentice Hall, Inc., 1961.

94. Nielsen, Kenneth F. (ed.) Proceedings of the Canadian Forage Crops Symposium. Saskatoon: Modern Press, 1969.

95. O'Callaghan, J.R. "The Systems Approach to Engineering Design", Journal and Proceedings of the Institution of Agricultural Engineers, XXIV (1), 1969, 31-36.

96. Otis, C.K. and Pomroy, J.H. "Density: A Tool in Silo Research", Agricultural Engineering, XXXVIII (12), 1957, 860-863.

97. Peart, R.M., Isaacs, G.W. and French, C.E. "Optimizing Materials-Handling Systems by Mathematical Programming", Transactions of the ASAE, VI (1), 1963, 26-31.

98. Pedersen, T.T. and Buchele, W.F. "Drying Rate of Alfalfa Hay", Agricultural Engineering, XLI (2), 1960, 86-89.

99. Preston, T.A. "A Computer Programme for the Evaluation of Alternative Methods", Canadian Agricultural Engineering, IX (2), 1967, 109-112.

100. Preston, T.A. "Some Applications of Critical Path Scheduling to the Layout and Operation of Piggeries", Canadian Agricultural Engineering, IX (1), 1967, 43-45 ff.

101. Priepke, E.H. and Bruhn, H.D. "Altering Physical Characteristics of Alfalfa to Increase the Drying Rate". Paper No. 69-143 for presentation at the 1969 Annual Meeting, American Society of Agricultural Engineers, Purdue University, W. Lafayette, Indiana, June 22-25.

102. ________________ "Projects in Forage Research", Special Publication SP-02-67. St. Joseph, Michigan: American Society of Agricultural Engineers, 1967.

103. Reitman, Julian. "When and Why Is Systems Engineering Used?" Proceedings of the 1964 Systems Engineering Conference, I. New York: Clapp & Poliak, Inc., 1964, 65-74.

104. Richey, C.B. (ed.) Agricultural Engineers' Handbook. New York: McGraw-Hill Book Company, Inc., 1961.

105. Robertson, Geo. W. and Russelo, D.A. "Astrometeorological estimator for estimating time when sun is at any elevation, elapsed time between the same elevations in the morning and afternoon, and hourly and daily values of solar energy, Q_o." Technical Bulletin 14, Agrometeorology Section, Plant Research Institute. Ottawa: Canada Department of Agriculture, 1968.

106. Russell, D.G. "Optimum Field Machinery Sizes for Alberta Farms". Unpublished M.Sc. Thesis, Department of Agricultural Engineering, University of Alberta, Spring, 1969.

107. Rutledge, P.L. "The Influence of the Weather on Field Tractability in Alberta". Unpublished M.Sc. Thesis, Department of Agricultural Engineering, University of Alberta, 1968.

108. Sammet, L.L. "Systems Engineering in Agriculture", Agricultural Engineering, XL (11), 1959, 663.

109. Schaper, L.A., Isaacs, G.W. and Dale, A.C. "Evaluating Heat Available for Drying in Natural Air", Transactions of the ASAE, IV (1), 1961, 140-141.

110. Schroeder, Morris E. "Random Forage Processing System with Batch Dehydration", VIth International Congress of Agricultural Engineering, III. Commission Internationale de Génie Rural, 1964, 1019-1031.

111. Shepperson, G. and Corrie, W.J. "Handling of Chopped Grass and Hay Before and After Storage", Proceedings of the Agricultural Engineering Symposium, September, 1967. ed. J.A.C. Gibb. London: Business Books Ltd., 1969, paper no. 3.

112. Shepperson, G. and Corrie, W.J. "Drying Chopped Hay", Proceedings of the Agricultural Engineering Symposium, September, 1967. ed. J.A.C. Gibb. London: Business Books Ltd., 1969, paper no. 6.

113. Slyke, R.M. Van. "Monte Carlo Methods and The PERT Problem, Operations Research, XI (5), 1963, 839-860.

114. Southwell, P.H. "An Analysis of Tractor Purchase Costs and Efficiencies", Canadian Agricultural Engineering, X (1), 1968, 33-37 ff.

115. Sowell, R.S. and Link, D.A. "Dynamic Programming Formulation of the Machinery Replacement Problem with Application to the Replacement of Cotton Picker". Paper No. 67-616 for presentation at the 1967 Winter Meeting, American Society of Agricultural Engineers, Detroit, Michigan, December 12-15.

116. Sowell, R.S. and Link, D.A. "Network Analysis and Mathematical Programming", Transactions of the ASAE, X (6), 1967, 820-828.

117. Stapleton, H.N. "Analyzing Field Machinery Systems by Computer", Agricultural Engineering, XLVIII (4), 1967, 202-203 ff.

118. Steel, Robert G.D. and Torrie, James H. Principles and Procedures of Statistics. New York: McGraw-Hill Book Company, Inc., 1960.

119. Stevens, Delwin M., and Becker, Clarence F. "How Mechanical Stackers Stack Up", Agricultural Engineering, XLVI (11), 1965, 626-627.

120. ____________ "System/360 Scientific Subroutine Package (360A-CM-03X) Version III - Programmer's Manual. IBM Application Program No. H 20-0205-3, 1968.

121. ____________ The Grain Grower. January, 1969, Section page 120.172.

122. ____________ The Grain Grower. September, 1967, Section page 100.120.

123. ____________ The Grain Grower. November, 1968, Section page 773.

124. ____________ "Types of Storages", Section 6.2, Agricultural Materials Handling Manual. Ottawa: The Queen's Printer, 1964.

125. United States. Department of Agriculture. The Yearbook of Agriculture 1948, Grass. Washington, D.C.: 1948.

126. Verma, T.R. and Toogood, J.A. "Infiltration Rates in Soils of the Edmonton Area and Rainfall Intensities", Canadian Journal of Soil Science, IL (1), 1969, 103-109.

127. Weller, John B. Farm Buildings, Vol. I, Techniques - Design - Profit. London: Crosby Lockwood & Son, Ltd., 1965.

128. Zimmerman, Mark. "Harvesting the Hay Crops", Implement and Tractor, LXXIX (5), 1964, 26-28.

129. Zimmerman, Mark. "Harvesting the Hay Crops, Part 2, Conventional Packages ... Bales", Implement and Tractor, LXXIX (6), 1964, 16-19 ff.

130. Zimmerman, Mark. "Harvesting the Hay Crops, Part 3: Condensed Packages", Implement and Tractor, LXXIX (7), 1964, 32-34 ff.

131. Zimmerman, Mark. "Harvesting the Hay Crops: Chopped Materials", Implement and Tractor, LXXIX (9), 1964, 20-22 ff.

132. Zimmerman, Mark. "Harvesting the Hay Crops: Long Loose Hay", Implement and Tractor, LXXIX (10), 1964, 36-38.

133. Zimmerman, Mark. "Summing Up Hay Harvesting: An Explosion of Alternatives and More to Come", Implement and Tractor, LXXIX (11), 1964, 26-28 ff.

APPENDICES

APPENDIX A

CENSUS DATA RELATED TO FORAGE PRODUCTION AND FORAGE HANDLING SYSTEMS IN ALBERTA

A1. Changes in Use of Improved Land in Alberta

A study of table A1 reveals the trend toward an increase in improved pasture and hayland area. Present cereal-crop market conditions and a growing interest in livestock production as an alternative will in all probability augment the trend. Sales of hay and fodder (see table A2) will likely increase accordingly, should forage become another cash crop with a ready market.

A2. Tame Hay Acreages Found on Commercial Farms

Although the trend is obvious on a total area basis, a closer study of the acreages of tame hay reported per farm underlines the relatively minor number of holdings controlling the majority of the total acreage. Taking the 1966 statistics on tame hay acreage intervals (see table A3) at their lower level, farms with more than 192 acres of tame hay would constitute 21.3% of the total tame hay acreage; farms with more than 127 acres would account for 38.3% of the total tame hay area. At their upper limits, acreages of 33 to 127 acres would comprise 75.5% of the total; at their lower limits 46.9% of the total. Although alfalfa and alfalfa mixtures account for over half of the tame hay acreage in C.D. #11, four arbitrary acreage sizes that might be chosen for a general comparison of forage handling systems are:

TABLE A1. CHANGES IN USE OF IMPROVED LAND IN ALBERTA[a]

	Commercial Farms 1961	1966	% Change
Total area of agricultural land (ac.)	37,241,021	40,986,692	10.0
Agricultural holdings (no.)	45,203	48,971	8.3
Acres per holding	824	837	1.6
Improved land (ac.)	20,978,849	24,308,687	15.9
Crops (ac.)	12,848,411	15,792,439	22.9
Improved pasture (ac.)	1,363,123	1,988,590	45.9
Summer fallow (ac.)	6,367,902	6,057,348	-4.9
Total tame hay (ac.)	1,929,767	2,466,501	27.8
Holdings reporting (no.)	28,763	32,123	11.7
Acres per holding	67.1	76.8	14.2
Oats cut for fodder (ac.)	967,232	1,000,357	3.4
Holdings reporting (no.)	37,623	40,579	7.9
Acres per holding	25.7	24.6	-4.2
Corn for ensilage or fodder (ac.)	314,651	546,319	73.6
Holdings reporting (no.)	33,659	33,155	-1.5
Acres per holding	9.4	16.5	76.2
Other fodder crops (ac.)	281,645	363,304	29.0
Holdings reporting (no.)	9,124	10,979	20.3
Acres per holding	30.9	33.1	7.2

[a]Source: Canada, Dominion Bureau of Statistics, 1966 Census of Canada, Vol. V, Agriculture, Catalogue No. 96-610 (Ottawa, 1968).

(1) 50 acres - close to the average alfalfa/alfalfa mixture acreage per holding in C.D. #11.

(2) 80 acres - close to the provincial average tame hay area per holding.

(3) 160 acres - a rough choice in the 128-192 acre interval that accounts for from 17.0% to 25.4%

TABLE A2. IMPORTANCE OF HAY AND FODDER SALES[a]

Item	Alberta	C.D. #11[b]	C.D. #15[b]
Wheat sold ($)	161,052,490	4,831,950	7,402,760
Census farms reporting (no.)	42,175	3,076	4,385
Sales per farm ($)	3,830	1,570	1,689
Other grains, including oil seeds sold ($)	78,186,870	7,075,480	14,973,010
Census farms reporting (no.)	35,167	3,472	6,466
Sales per farm ($)	2,224	2,037	2,315
Hay and fodder sold ($)	10,730,800	665,450	5,226,350
Census farms reporting (no.)	9,330	1,054	2,341
Sales per farm ($)	1,150	631	2,233

[a] Source: same as Table A1.

[b] Census Divisions 11 and 15 were selected because of their significant contribution to the total forage sales in Alberta and the importance of the Edmonton area to the analysis.

TABLE A3. TAME HAY ACREAGES IN ALBERTA[a]

			Commercial Farms			
Tame Hay, Total	1956	%	1961	%	1966	%
Census-farms reporting	38,051	100.0	42,983	100.0	42,770	100.0
1-4 acres	1,789	4.7	1,084	2.5	648	1.5
5-7 "	2,730	7.2	1,802	4.2	1,236	2.9
8-12 "	5,654	14.9	4,068	9.5	2,947	6.9
13-17 "	3,326	8.7	2,894	6.7	2,254	5.3
18-32 "	9,310	24.5	9,537	22.2	8,422	19.7
33-47 "	4,610	12.1	5,877	13.7	5,831	13.6
48-72 "	4,775	12.5	7,041	16.4	7,645	17.9
73-127 "	3,749	9.9	6,569	15.3	8,171	19.1
128-192 "	1,229	3.2	2,415	5.6	3,267	7.6
193-277 "	545	1.4	1,013	2.4	1,489	3.5
278 acres and over	354	0.9	683	1.6	860	2.0

[a]Source: Same as Table A1.

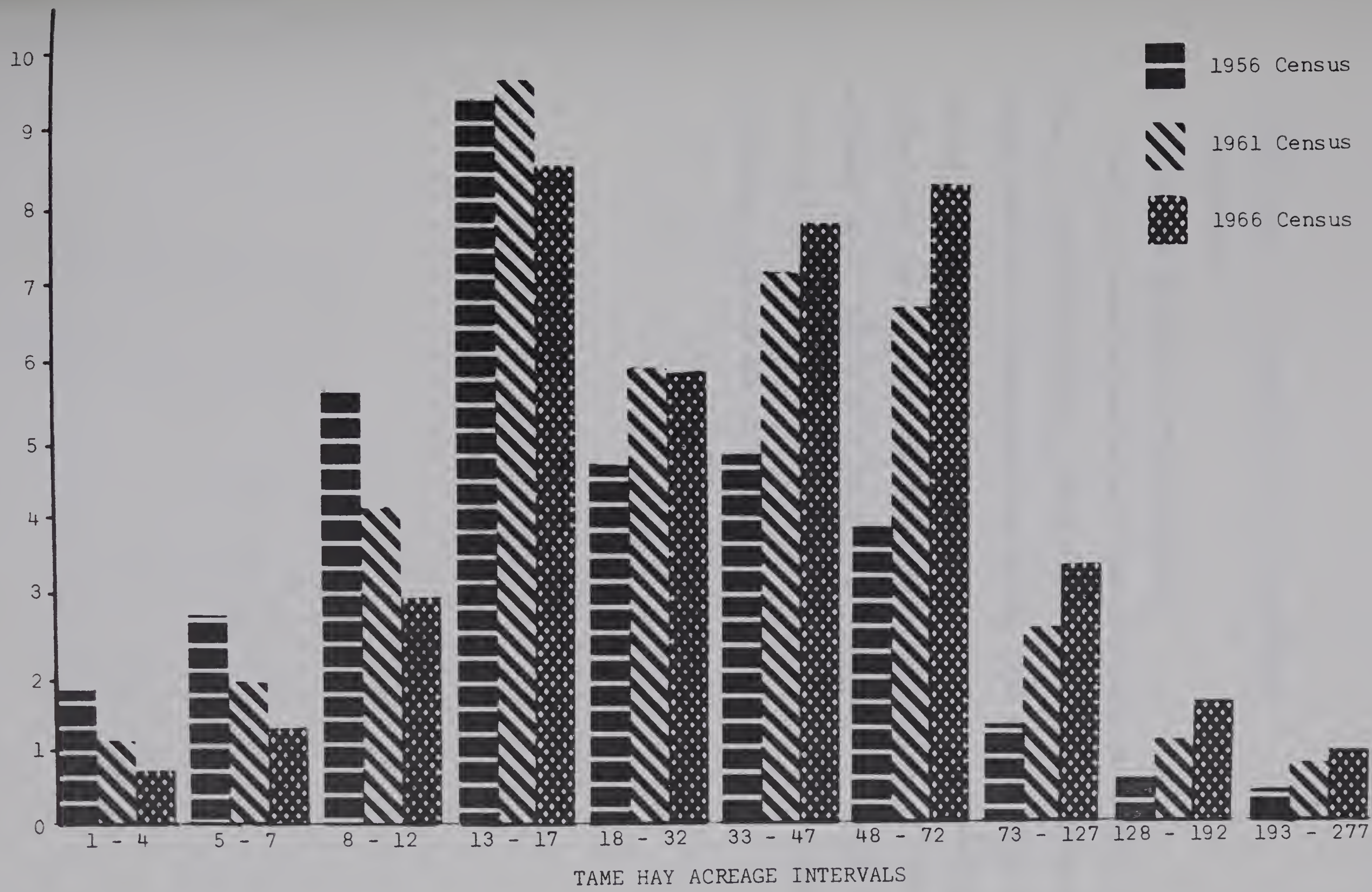


FIGURE A1. COMMERCIAL FARMS IN ALBERTA REPORTING TAME HAY ACREAGES.

(4) 300 acres - a guideline for any attempted prognosis.

A3. Equipment Related to Forage Handling

Table A4 presents some data on farm machinery on commercial farms in Canada and Alberta, particularly on machines frequently incorporated into a forage handling system. The figures tell us nothing about the changes that have been made in forage handling systems, but seem to indicate little change in the type of major equipment used. Notice that the average farm has two tractors and that baled hay is still more prevalent than silage if the numbers of machine units are any indication.

TABLE A4. FARM MACHINERY NUMBERS ON COMMERCIAL FARMS IN CANADA[a]

Item	Canada 1961	Canada 1966	Alberta 1961	Alberta 1966	Alberta % of national total (1966)
Motor trucks	211,614	274,610	53,512	70,335	25.6
Holdings reporting	171,142	197,621	39,252	44,822	
Units per holding[b]	1.24	1.40	1.36	1.57	
Tractors	379,734	465,813	74,569	90,395	19.4
Holdings reporting	240,187	259,361	43,409	46,574	
Units per holding[b]	1.58	1.80	1.72	1.94	
Swathers	..	113,249	24,297	32,465	28.7
Holdings reporting	..	106,141	23,330	30,387	
Units per holding[b]	..	1.07	1.04	1.07	
Pick-up hay balers	75,204	117,302	13,967	22,564	19.2
Holdings reporting	74,434	115,462	13,769	22,055	
Units per holding[b]	1.01	1.02	1.01	1.02	
Forage crop harvesters	14,825	21,894	1,879	3,029	13.8
Holdings reporting	14,314	20,758	1,788	2,882	
Units per holding[b]	1.04	1.05	1.05	1.05	
Proportion of balers to forage crop harvesters	5.07	5.36	7.43	7.45	

[a]Sources: Canada, Dominion Bureau of Statistics, 1966 Census of Canada, Agriculture, Vol. III, Catalogue No. 96-601 and Vol. V, Catalogue No. 96-610 (Ottawa, 1968).

[b]Two decimal places are used merely to underline the fact that little change occurred.

APPENDIX B

POWER REQUIREMENTS FOR FORAGE HANDLING EQUIPMENT

Power requirements are given on the basis of 100% field efficiency and will, of course, vary with management and operational practices. For some items of equipment, manufacturers specify the minimum pto hp requirements.

TABLE B1. POWER REQUIREMENTS FOR FORAGE HANDLING EQUIPMENT

Item of Equipment	Typical Power Requirements	Source
Field chopper, grass silage, $\frac{1}{2}$-in. theoretical cut	1 - $2\frac{1}{2}$ hp-hr/ton	ASAE Yearbook (48)
Field chopper, cured hay, 3-in. theoretical cut	$1\frac{1}{2}$ - 3 hp-hr/ton DM	"
Forage blower, handling silage	1 - $1\frac{1}{2}$ hp-hr/ton	"
Hay baler	$1\frac{1}{4}$ - $2\frac{1}{2}$ hp-hr/ton	"
Hay conditioner, 6-ft.	3 - 6 hp	"
Mower	1/3 - 2/3 hp/ft of cut	"
Rotary chopper, flail	1 1/3 - $2\frac{1}{2}$ hp-hr/ton	"
Rotary chopper, horizontal	$2\frac{1}{2}$ - $3\frac{1}{2}$ hp-hr/ton	"
Mower conditioners, flail	5 - 10 hp/ft of cut	Kjelgaard (74)
Forage harvester, 3-in. theoretical cut	$\frac{3}{4}$ - $1\frac{1}{4}$ hp-hr/ton DM	Bainer, Kepner and Barger (5)[a]
Forage harvester, 2-in. cut hay	4/5 hp-hr/ton DM	"
Forage harvester, 2-in. cut, haylage	$1\frac{1}{2}$ hp-hr/ton DM	"
Forage harvester, 2-in. cut, silage	$1\frac{3}{4}$ hp-hr/ton DM	"
Forage harvester, 1-in. cut, hay	$1\frac{1}{2}$ hp-hr/ton DM	"
Forage harvester, 1-in. cut, haylage	$2\frac{1}{4}$ hp-hr/ton DM	"
Forage harvester, 1-in. cut, silage	2 hp-hr/ton DM	"
Forage harvester, $\frac{1}{2}$-in. cut, hay[b]	2 hp-hr/ton DM	"
Forage harvester, $\frac{1}{2}$-in. cut, haylage[b]	3 hp-hr/ton DM	"
Forage harvester, $\frac{1}{2}$-in. cut, silage[b]	$2\frac{1}{2}$ hp-hr/ton DM	"
Wagon unloader	$\frac{1}{4}$ - $\frac{1}{2}$ hp	Richey (104)
Pull-type pto-driven balers	8 - 10 hp	Hundtoft and Guest (62)

[a]Approximated from a graph.

[b]Extrapolated.

APPENDIX C

CAPACITY DATA FOR FORAGE HANDLING EQUIPMENT

C1. Width-Dependent Capacity Calculations

Effective machine capacities were calculated using the following equation taken from the ASAE Yearbook (48):

$$C = SWE/825$$

where C = effective field capacity in ac/hr

S = travel speed in mph

W = rated width of machine in action, in feet

E = field efficiency, in percent

Since some types of machines took on varying widths in the two GPSS programs, a common figure was stored as

$$C = 1000\ SE/825$$

where C = effective field capacity in 1000 x ac/hr-ft

The multiple, of course, was used to compensate for the decimal accuracy that would be lost in truncation to an integer quantity. Table C1 includes the ranges of speeds and efficiencies that have been used for some of these machines. The coefficients inserted in matrix MH3 of both programs were calculated for low efficiency and low speed, low efficiency and high speed, high efficiency and low speed, and high efficiency and high speed. The largest of these four alternatives was used in subroutine RATE1 for the two simulation runs that were completed.

C2. Power-Dependent Capacity Calculations

According to Bainer, Kepner and Barger (5), the theoretical maximum capacity of a forage harvester could be calculated using the manufacturer's specification sheet and geometrical relationships.

TABLE C1. EFFICIENCY AND SPEED DATA

Machine	Efficiency %	Speed (mph)
Mower[a]	75 - 85	3.5 - 5.5
Mower and conditioner[b]	75 - 83	3.3 - 5.4
Side-delivery rake[a]	75 - 90	3.5 - 5.0
Rake[b]	62 - 89	3.5 - 7.2
SP windrower[a]	75 - 85	3.5 - 4.5
Windrower[b]	63 - 81	1.8 - 3.5
Forage harvester	50 - 75[a]	3.3 - 4.6[b]
Multi-treatment machine[c]	75 - 85	3.5 - 5.5
Forage harvester, trailers alongside[d]	> 85	
Forage harvester, trailers towed[d]	70	
Baler alone	65 - 80[a]	1.5 - 4.6[b]
Baler plus wagon	55 - 70[a]	
Dehydrator (rotary drum drier)	50 - 85[e]	
Wagons (thrown bales)	80[f]	

[a]First choice for data to be used in the two GPSS programs. Source: The ASAE Yearbook (48).

[b]Source: The Grain Grower (122).

[c]Speed and efficiency assumed close to those of the mower.

[d]Source: Shepperson and Corrie (112).

[e]Source: Paper presented by Fortin (20).

[f]Source: Hundtoft and Guest (62). Space efficiency calculated using a dry density of shorter bales as 7 pcf.

However, this figure would far exceed the actual capacity due to unavoidable variations in moisture content, swath density, field conditions, state of repair of the machine and operator expertise. The following equation was used in establishing a theoretical field capacity for any particular forage harvester:

$$C = PE/(QY(100 + R))$$

where C = effective field capacity in standard ac/hr

P = available power in pto hp

E = field efficiency of the harvester in percent

Q = power requirement of the forage in pto hp-hr/ton DM

Y = yield in tons DM/ac

R = rest allowance in percent

C3. Capacity Calculations for Chain-and-Flight Conveyors

The volumetric capacities of a chain-and-flight conveyor depend on flight dimensions and spacing, chain speed, the effective angle of repose of the material being handled, and the angle of elevation of the conveyor. Richey (104) stated that the capacity of an inclined conveyor compared with level capacity is 90% at 20^{o}, 80% at 25^{o}, 70% at 30^{o} and 60% at 35^{o}, particularly when handling granular materials. Apparently, maximum limits on flight capacities may supersede the capacities calculated using the variables first mentioned in this paragraph.

Setting aside this latter consideration for the moment and calculating capacities according to flight dimensions, angle of repose, and angle of elevation, the following procedure could be used. Given

V = volume of flight in cubic inches

α = angle of repose in degrees

β = angle of elevation in degrees

l = flight spacing in inches

w = flight width in inches

d = flight depth in inches

let $\gamma = \alpha - \beta$ where $\alpha > \beta$

and let $\gamma = \alpha + 90 - \beta$ where $\alpha < \beta$ (see figure C1).

In the case of $\alpha < \beta$,

$$V = \frac{1}{2} wd^2 \tan\gamma$$

if some of the bottom of the flight space is visible, or

$$V = (wl(d - l\tan\gamma/2)$$

if the bottom of the conveyor deck is completely covered.

Where $\alpha > \beta$, total volume is equal to the cubic space of the level-full flight plus the heaped material above that -- sloped in two planes. Using the labels indicated in figure C1,

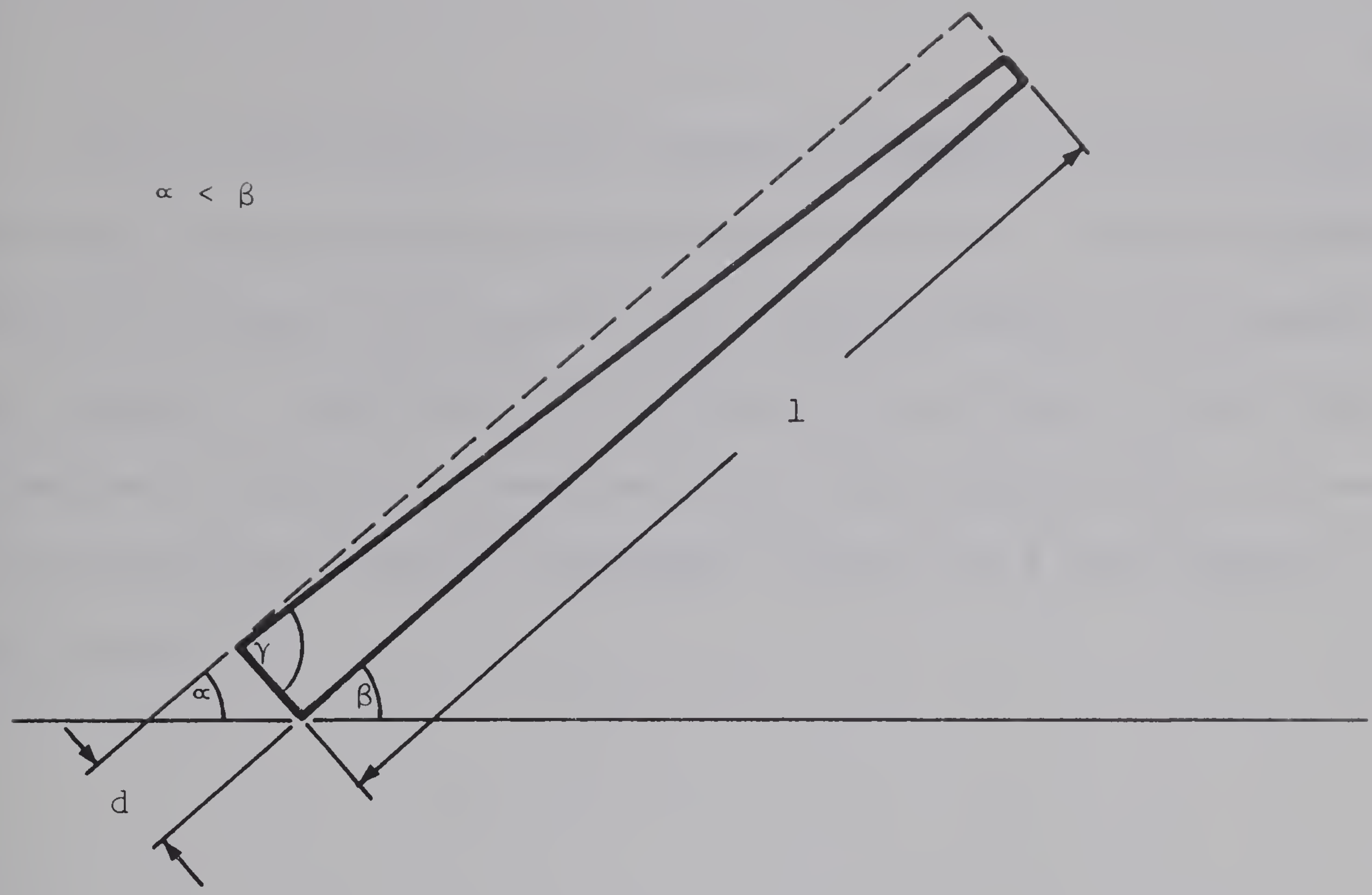
$$l_a = h_a \tan (90 - \alpha - \beta)$$

$$= \frac{l \tan (90 - \alpha - \beta)}{\tan (90 - \alpha - \beta) + \tan (90 - \alpha + \beta)}$$

$$l_b = l - l_a$$

$$V = wld + \int_{L=0}^{L=l_b} \frac{wh}{2} L + \int_{L=l_a}^{L=l} \frac{wh}{2} L$$

$$= wld + \frac{w}{6} (\tan\gamma l_b^3 + \tan (\alpha + \beta) l_a^3)$$



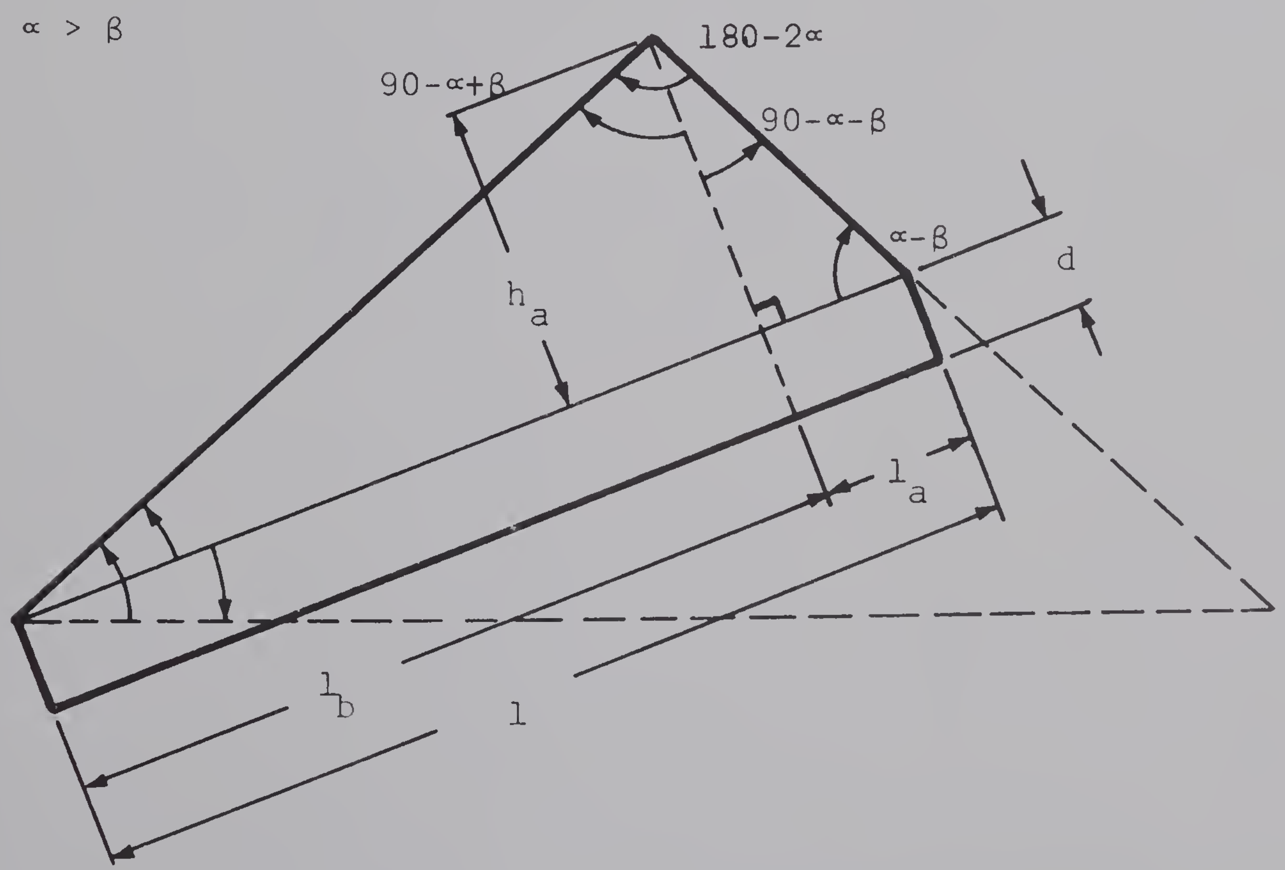


Figure C1. Side views of flight load patterns.

For purposes of this study, arbitrary limits were placed on flight capacities since the effects of mechanical vibration, irregular loading conditions, slump of the material, and initial peaking of the material were unknown. Coefficients of friction of the forage on steel plate, a function of moisture content, were taken from Richey (104) to be used in calculating the electric horsepower required for a given capacity (see Appendix I).

APPENDIX D

COST DATA FOR FORAGE HANDLING EQUIPMENT

D1. Observed Distribution of Cost Data

Southwell's (114) Ontario studies showed that using larger conventional power units reduces capital expenditure per unit performance by 3% to 4% without influencing efficiencies. His analysis of suggested retail prices indicated that diesel tractors require 10% more capital per pto hp and 6% more capital per dbhp than do gasoline tractors. In addition, conversion efficiency was not related to tractor size. In line with these findings, tractor cost was split into two items, gasoline and diesel tractor costs, for the two simulation programs.

Table D1 summarizes the cost observations made -- these cost data collected from various farm machinery dealers in the Edmonton vicinity during 1969. Note that not all types, sizes or manufactures of a given item of equipment are necessarily included in the tables. Also, cost figures do not take into account discounts for trade-in or cash sales.

D2. Depreciation and Repair Rates

Straight-line depreciation rates were used, 10% of the initial cost taken as the arbitrary scrap value. The depreciation rate used depended on the item in question and on the maximum allowable rate for income tax purposes (see table D2). Repair costs are largely dependent on the operator and managerial skills available. Both per annum fixed costs and repair costs may be spread over two or more farm enterprises. Proportions will alter with the partial

TABLE D1. MACHINERY COST AND CAPACITY DATA[a]

Item of Equipment	Observations	Manufacturers	Sizes	Capacity					Total Cost in Dollars			
	No.	No.	No.	Units	Min.	Max.	Mean	S.D.[b]	Min.	Max.	Mean	S.D.[b]
Farm wagons (less tires)	7	2	5	T. payload	3	7½	5.2	1.47	134.50	280.00	191.82	46.74
Self-unloading forage boxes	10	5	9	ft^3 capacity	298	700	477.4	139.3	750.00	2400.00	1767.88	484.91
Farm truck chasses	14	2	7	T. payload	1.32	12.46	5.27	3.14	3457.00	9400.00	4956.57	1631.64
Custom truck boxes (installed)	80	1	69	ft^3 capacity	154	823	445.0	159.1	310.00	815.00	526.25	121.46
Gasoline tractors	12	5	12	pto hp	26.35	66.11	43.65	11.30	3500.00	8250.00	5125.33	1513.16
Diesel tractors	27	6	27	pto hp	26.64	131.48	65.25	27.18	3775.00	16850.00	8149.26	3413.58
Tower silo unloaders	9	3	4	silo diameter (ft)	16	30	21.6	4.4	1500.00	2416.00	1919.67	292.07
Wheel rakes	15	7	7	width (ft)	7½	15	9.96	2.30	560.00	1204.00	788.00	175.15
Side-delivery rakes[c]	5	4	5	width (ft)	7	9½	8.4	0.96	810.00	1024.00	884.40	84.21
SP windrower (no conditioner)	5	5	4	width (ft)	12	15	13.3	1.30	3315.00	4120.00	3560.00	323.57
SP windrower (conditioner)	7	5	5	width (ft)	8	15	12.6	2.32	4221.00	9500.00	5752.43	2005.32
Multi-treatment machines	8	7	5	width (ft)	7	12	9.28	1.37	1750.00	3900.00	2893.50	589.74
Heavy-duty forage harvester with cutter bar	6[d]	6	5	width (ft)	6	10	7.7	1.4	4282.00	5782.00	4887.38	528.77

[a]This table is not all inclusive but does give an adequate cross-section of equipment costs in the Edmonton area for 1969.

[b]Standard deviation.

[c]Includes parallel-bar rakes.

[d]Three cylinder- and three flywheel-type cutterheads included.

TABLE D2. MACHINERY DEPRECIATION AND REPAIR DATA

Item of Equipment	Estimated Wear-Out Life	Total Repairs in Wear-Out Life	Estimated Life in Years Used for Depreciation Schedules		
	hr	% List Price	A[a]	B[b]	C[c]
Stationary power unit	12,000[d]	120	10	-	-
Tractor, 2-wheel drive	12,000	120	6 2/3	8 - 12	-
Windrower, self-propelled	2,500	100	6 2/3	10	-
Mower	2,000	120	10	15	15
Hay rake, side delivery	2,500	100	10	15	15
Hay conditioner	2,500	100	10	10	15
Ensilage loader	2,000	100	10	-	-
Front-end loader	2,500	60	10	15	15
Hay baler, engine drive	2,500	60	6 2/3	8	-
Hay baler, pto drive	2,500	80	10	8	-
Harvester, flail	2,000	80	10	-	-
Harvester, forage, pull-type	2,000	80	10	10	15
Harvester, forage, self-propelled	2,000	60	6 2/3	-	-
Ensilage blower	2,000	80	10	-	15
Wagon and box	5,000	100	6 2/3	15	15
Farm truck	4,000	80	6 2/3	-	-
Farm wagon, power unloading	2,500	100	6 2/3	-	-
Wheel rakes	2,500[e]	100	10	-	-
Multi-treatment machines, pull-type	2,000[f]	120	10	-	-
Bale throwers	2,500[g]	80	10	-	-
Bale accumulators	2,500[g]	80	6 2/3	-	-
Bale stookers, bunchers, and field loaders	2,500[h]	100	10	-	-
Bale wagons, pull-type	2,500[i]	40	6 2/3	-	-
Bale wagons, self-propelled	2,500[i]	40	6 2/3	-	-
Hay cubers, self-propelled	2,000[j]	60	6 2/3	-	-
Hay cubers, stationary	2,000[k]	80	10	-	-
Tower silo unloaders	2,000[l]	25	10	-	-
Elevators and conveyors	2,000[l]	25	10	-	-
Hay mills and recutters	2,000[m]	80	10	-	-
Hay stackers	2,500[g]	80	10	-	-
Stack movers	2,500[g]	80	6 2/3	-	-

TABLE D2. (continued)

[a]Depreciation rates are those permitted for income tax purposes and also used in this analysis.

[b]Source: Greer, Henderson and Schepler (54).

[c]Source: Maish, Cuykendall and Hasbargen (85). Note: 10-year old tractors were used with a value of 65% of new cost. In 15 years, the equipment would be worn out or obsolete.

[d]The first 17 items have their wear-out life and repair rates taken from the ASAE Yearbook (48).

[e]Roughly equivalent to the side-delivery rake.

[f]Assumed more akin to the mower than the windrower.

[g]As for pto-driven hay balers.

[h]Assumed.

[i]Wear-out life assumed equivalent to that of the pto-driven hay baler. Repair rates taken from The Grain Grower, section page 700.

[j]Assumed equivalent to the self-propelled forage harvester.

[k]Assumed equivalent to the pull-type forage harvester.

[l]Wear-out life assumed equivalent to that of the ensilage blower. Decker's (36) repair rate used.

[m]Assumed equivalent to the ensilage blower.

budgeting decided on by the manager -- but for this more general case, such parameters are set. Per annum fixed costs of self-propelled windrowers, front-end loaders and attachments, and wagons were attributed entirely to the forage enterprise. Similar costs for tractors were shared on the basis of annual use in hours. An arbitrary figure of 600 hours per year, as used by Moggach (89), was selected, and the operating hours per year spent on the forage handling system decided the fraction of fixed and repair costs to be ascribed to the forage enterprise. This 600-hour figure was somewhat high for Census Division No. 11, but it ensured that less than 100% of the tractor fixed costs accrued to the forage system.

The network was constructed so as to always include the tractor on cutting and harvesting equipment as an owned item. Power units required elsewhere for moving the forage were treated as either owned or hired -- once selected, the choice was irrevocable for the remainder of the year being simulated.

D3. Equipment - Cost Data Input

Cost data were input to the program in different ways. Some were introduced in matrix form at the outset of the program. Table D3 lists some of these constants, some used to calculate other constants, which were called out of storage as required. In some cases, cost data were adequately approximated by regression equations (see table D4). The point on the X-axis was selected, then the corresponding Y-value (cost) calculated.

TABLE D3. ANNUAL FIXED COSTS AND HOURLY REPAIR COSTS OF FORAGE HARVESTING AND HANDLING EQUIPMENT

Item of Equipment	Total Cost ($)	Per Annum Fixed Cost[a] (x years) ($)	Per Annum Fixed Cost[b] (15 years) ($)	Repair Cost[c] (¢/hr)
Forage harvesters, flail type	1,850	360.75	299.15	74
	1,942	378.69	314.02	78
	1,776[d]	346.32	287.18	71
Forage harvesters, heavy-duty, pull-type with cutter bar and flywheel-type cutterhead	3,316	646.62	536.20	133
	4,282	834.99	692.40	171
	4,739	924.11	766.30	190
	4,595	896.03	743.01	184
Forage harvesters, as above but with cylinder-type cutterhead	5,200	1014.00	840.84	208
	5,782	1127.49	934.95	231
	4,727	921.77	764.36	189
Forage harvesters, self-propelled with cutter bar	17,145[d]	4200.53	2772.35	514
	17,940[d]	4395.30	2900.90	538
Forage harvesters, heavy-duty, pull-type with pick-up and flywheel-type cutterhead	3,721	725.60	601.69	149
	4,900	955.50	792.33	196
	3,965	773.18	641.14	159
	4,409	859.76	712.94	176
	4,047	789.17	654.40	162
Forage harvesters, heavy-duty, pull-type with pick-up and cylinder-type cutterhead	3,980	776.10	643.57	159
	3,800	741.00	614.46	152
	3,800	741.00	614.46	152
Forage harvesters, self-propelled with hay pick-up	24,730	6058.85	3998.84	742
	16,570[d]	4059.65	2679.37	497

TABLE D3. (continued)

Item of Equipment	Total Cost ($)	Per Annum Fixed Cost (x years)[a] ($)	Per Annum Fixed Cost (15 years)[b] ($)	Repair Cost[c] (¢/hr)
Forage blowers, short, auger-type hopper	872	170.04	141.00	35
	690	134.55	111.57	28
	664	129.48	107.37	26
	1,240	241.80	200.51	50
	794	154.83	128.39	32
	825	160.88	133.40	33
Forage blowers, long, conveyor-type hopper	1,120	218.40	181.10	45
	1,050	204.75	169.79	42
	1,055	205.73	170.59	42
	1,111	216.65	179.65	45
	1,185	231.08	191.61	47
Silage distributor ($\frac{1}{4}$ hp motor)	305[e]	56.42	46.27	
Mowers, trailer-type	685	133.58	110.76	41
	742	144.69	119.98	45
	849	165.56	137.28	51
	800	156.00	129.36	48
	900	175.50	145.53	54
	700	136.50	113.19	42
Hay crimpers and conditioners, trailer-type	1,185	231.08	191.61	47
	1,108	216.06	179.16	44
	1,139	222.11	184.18	46

TABLE D3. (continued)

Item of Equipment	Total Cost ($)	Per Annum Fixed Cost[a] (x years) ($)	Per Annum Fixed Cost[b] (15 years) ($)	Repair Cost[c] (¢/hr)
Side-delivery rakes, trailer-type	810	157.95	130.98	32
	898	175.11	145.21	36
	850	165.75	137.45	34
	840	163.80	135.83	34
	1,024	199.68	165.58	41
Side-delivery rakes, three-point mounted	755	147.23	122.08	30
	683	133.19	110.44	27
Wheel rakes, trailer-type	580	113.10	93.79	23
	715	139.43	115.62	29
	805	156.98	130.17	32
	905	176.48	146.34	36
	685	133.58	110.76	27
	765	149.18	123.70	31
	890	173.55	143.91	36
	650	126.75	105.11	26
	887	172.97	143.43	35
	597	116.42	96.54	24
	822	160.29	132.92	33
	1,015	192.93	164.13	41
	1,204	234.78	194.69	48
Multi-treatment machines, trailer-type	1,750	341.25	282.98	105
	2,900	565.50	468.93	174
	2,972	579.54	480.57	178
	2,890	563.55	467.31	173
	2,650	516.75	428.51	159
	3,000	585.00	485.10	180
	3,086	601.77	499.00	185
	3,900	760.50	630.63	234

TABLE D3. (continued)

Item of Equipment	Total Cost ($)	Per Annum Fixed Cost (x years)[a] ($)	Per Annum Fixed Cost (15 years)[b] ($)	Repair Cost[c] (¢/hr)
Windrowers, self-propelled less conditioner	3,315	812.18	536.04	133
	3,400	833.00	549.78	136
	4,120	1009.40	666.20	165
	3,544	868.28	573.07	142
Windrowers, self-propelled plus conditioner	4,392	1076.04	710.19	176
	4,520	1107.40	730.88	181
	5,520	1352.40	892.58	221
	4,634	1135.33	749.32	185
Balers, heavy-duty, pull-type	2,700	526.50	436.59	86
	2,646	515.97	427.86	85
	2,922	569.79	472.49	94
	2,700	526.50	436.59	86
	2,950	575.25	477.02	94
	2,600	507.00	420.42	83
	3,200	624.00	517.44	102
Baler, self-propelled	10,025	2456.13	1621.04	241
Bale throwers	692	134.94	111.90	22
	725	141.38	117.23	23
	720	140.40	116.42	23
	640	124.80	103.49	20
Auto-stooker	825	160.88	133.40	
10-bale manned stooker	250	48.75	40.43	

TABLE D3. (continued)

Item of Equipment	Total Cost ($)	Per Annum Fixed Cost[a] (x years) ($)	Per Annum Fixed Cost[b] (15 years) ($)	Repair Cost[c] (¢/hr)
Bale buncher	150	29.25	24.26	
Flat-8 bale accumulator plus front-end loader attachment	2,000	490.00	323.40	80
Field bale-loader	490	95.55	79.23	20
Bale wagons, pull-type	7,080	1734.60	1144.84	113
	5,148	1261.26	832.43	82
Bale wagon, self-propelled	12,763	3126.94	2063.78	204
Horizontal-silo unloaders	2,654[d]	517.53	429.16	133
	2,586[d]	504.27	418.16	129
	2,576	502.32	416.54	129
	2,730[d]	532.35	441.44	136
Hay stackers	14,570[d]	2841.15	2355.97	466
	8,440[d]	1645.80	1364.75	271
Stack movers	2,650	649.25	428.24	85
	2,900	710.50	468.64	93
	2,790[d]	683.55	450.86	89
Windrow turner, two-wheel finger-rake	225	43.88	36.38	09
Side-tip wagon, hydraulically operated, maximum load of eight tons	3,250	796.25	525.53	65

TABLE D3. (continued)

Item of Equipment	Total Cost ($)	Per Annum Fixed Cost (x years)[a] ($)	Per Annum Fixed Cost (15 years)[b] ($)	Repair Cost[c] (¢/hr)
Hay cubers, stationary	11,800	2301.00	1908.06	472
	11,768[d]	2294.76	1902.89	471
Hay cubers, self-propelled	41,000	10045.00	6629.70	1230
	35,850[d]	8783.25	5796.95	1076
	35,705[d]	8747.73	5773.50	1071
Hay mill	2,909	567.26	470.39	116
Recutters, the second with flaker attachment	2,758	537.81	445.97	110
	3,471	676.85	561.26	138
Front-end loaders, with 60" bucket and tines	1,150	224.25	185.96	28
	1,210	235.95	195.66	29
Front-end loader with sweep	1,615	314.92	261.15	39
Bale-fork attachment, 6 bale	60	11.70	9.70	02
Bale-fork attachment, 10 bale	84	16.38	13.58	02
60" bucket attachment	152	29.64	24.58	04
Sweep attachment	315	61.42	50.94	08
Large scoop attachment (21 ft^3)	160	31.20	25.87	04
Grapple-fork attachment	304	60.28	49.16	07
	180	35.10	29.11	04

TABLE D3. (continued)

Item of Equipment	Total Cost ($)	Per Annum Fixed Cost (x years)[a] ($)	Per Annum Fixed Cost (15 years)[b] ($)	Repair Cost[c] (¢/hr)
Push-off stacker attachment	354 445	69.03 86.78	57.24 71.96	08 12
Chain-and-flight conveyor, 62' with running gear, 14" spacing and feeder box	1,283	250.19	207.46	16
Chain-and-flight conveyor, 18' with running gear and 14" spacing	400	78.00	64.68	05
Chain-and-flight extension per ft. (10' basis) with 14" spacing	10	1.95		

Note: For any particular item of equipment with multiple entries, these entries are in the same order as they are introduced into the program(s) they apply to (see Appendices G and H).

[a]Depreciation rates are those listed under Schedule A in table D2.

[b]Depreciation rate used by Maish, Cuykendall and Hasbargen (85).

[c]Based on an estimated wear-out life in hours and on an estimated total repair cost expressed as a percent of list price.

[d]Calculated cost delivered to Edmonton using F.O.B. factory prices and 1969 railway freight rates for agricultural implements, 20,000 lb minimum carload weight. All U.S. price quotations converted to Canadian dollars ($C ÷ $US (1.08)).

[e]No housing requirement.

TABLE D4. EQUIPMENT FIXED-COST APPROXIMATIONS.

Item of Equipment	X	$ cost = sX	Zero Order Correlation Coefficient	$ cost = a + bX			
	units	s ($/unit)		a ($)	b ($/unit)	Standard Error of Regression Coefficient ($/unit)	Computed t-value
Farm wagons (less tires)	T. payload	38.80	0.913	40.17	29.08	5.80	5.02
Self-unloading forage boxes	ft^3 capacity	3.70	0.313[a]	1147.14	1.37	1.13	1.21
Farm truck chasses	T. payload	940.53	0.882	2545.50	457.89	70.74	6.47
Custom truck boxes (installed)	ft^3 capacity	1.18	0.936	208.22	0.71	0.03	23.56
Gasoline tractors	pto hp	117.42	0.945	-399.73	126.58	13.84	9.15
Diesel tractors	pto hp	124.87	0.964	249.64	121.06	6.69	18.09
Tower silo unloaders	silo diameter (ft)	88.87	0.786	807.07	51.62	15.35	3.36
Wheel rakes	width (ft)	78.11	0.892	111.20	67.95	9.58	7.10
Side-delivery rakes	width (ft)	105.29	0.637	416.27	55.73	38.99	1.43
Multi-treatment machines[b]	width (ft)	311.80	0.955	-935.77	412.58	52.06	7.92
SP windrower (no conditioner)[b]	width (ft)		0.792	946.94	196.47	87.54	2.24
SP windrower (conditioner)[b]	width (ft)		0.237	3163.82	204.75	375.17	0.546
H-D harvester with cutter bar[bc]	width (ft)		0.482	3493.54	181.81	165.16	1.10

[a] This item was approximated in the programs by a linear regression equation in spite of the low correlation, primarily because another uncomplicated method was unavailable and all transport units could be handled similarly in one routine.

[b] Low sample size, low correlation or existence of another suitable approach obviated the need for these regression equations.

[c] Three cylinder- and three flywheel-type cutterheads included.

Dehydrator equipment costs were some of those data calculated before insertion into the program. The total cost delivered to Edmonton included an 8% exchange rate plus the shipping costs from the factory at 20,000-pound maximum carload rates for agricultural implements. Material costs included a six-inch concrete pad reinforced with 6" x 6" 10/10 wire mesh under the feeder and dehydrator and reinforced with 1/2 inch Re-bar at six-inch intervals in both directions under the apron. This arbitrary concrete support will, of course, vary with different weight-bearing capacities of soils and changing traffic loads expected at these points. Table D5 outlines the steps used in composing the \$84,320 constant used in Appendix G. For determination of weather protection costs, the total area of 1476 ft^2 was approximated as 1500 ft^2.

TABLE D5. FIXED COST OF DEHYDRATING EQUIPMENT

Item		Cost
Total delivered cost (98,680 lb) to the nearest dollar		\$79,376
5% contingency allowance		3,968[a]
Concrete: 738 ft^3 at \$18/yd^3	\$492.00	
Re-bar: 1280 ft at \$8.10/100 ft	103.68	
Mesh: 1156 ft^2 at \$45/1000 ft^2	51.20	
Total material costs		647
Labour costs taken as 50% of material costs		323
Total approximate cost less weather protection		\$84,314

[a]Covers such things as station-to-farm transport costs and set-up costs.

APPENDIX E

ASTROMETEOROLOGICAL ESTIMATOR PROGRAM

For some sets of work/non-work criteria used in analyzing historical weather data and subsequently obtaining cumulative probability curves, day length and solar radiation data were required for specified days of the year. Tables are available for selected days and selected latitudes (79), but interpolation would be required for values applicable to the Edmonton area. Programs developed by Robertson and Russelo (105) for operation on the I.B.M. 1620 computer include calculation of day length and daily solar radiation at the top of the atmosphere for any latitude and longitude. The following listings are essentially the same programs with format modifications and one or two procedural changes. The programs, run successively on the I.B.M. 360/67 computer, produced the required data in card form to be used as an input data set for the program listed in Appendix F.

```
          C
          C      FORTRAN PROGRAM.  SOLAR EPHEMERIC DATA ESTIMATOR.
          C      ---------------------------------------------------
          C SOURCE: C.W. ROBERTSON AND D.A. RUSSELO, ''SOLAR EPHEMERIC DATA
          C             ESTIMATOR'',FORTRAN PROGRAM 1044-04-31, AG. MET. TECH.
          C             BULLETIN #14 (OTTAWA : AGROMETEOROLOGICAL SECTION, PLANT
          C             REAEARCH INSTITUTE, RESEARCH BRANCH, C.D.A., 1968), 7.
          C
          C NOTE : ALTHOUGH THE FORMAT IS ALTERED SLIGHTLY, THE INPUT DATA
          C NOTE : REMAINS THE SAME.
ISN    1         DIMENSION A(4,5),B(4,4),SUM(4),D(6)
          C
          C      READ IN REGRESSION COEFFICIENTS.
          C
ISN    2         DO 10 I=1,4
ISN    3      10 READ(5,1) (A(I,J),J=1,5),(B(I,J),J=1,4)
ISN    4       1 FORMAT (5E10.4/4E10.4)
ISN    5         WRITE (6,3)
ISN    6       3 FORMAT ('1',5X,'REGRESSION',20X,'EQUATION',5X,'RADIUS')
ISN    7         WRITE (6,4)
ISN    8       4 FORMAT (5X,'COEFFICIENT',4X,'DECLINATION', 6X,'OF TIME',5X,'VECTOR
                1'/)
ISN    9         DO 12 J=1,5
ISN   10         JM1=J-1
ISN   11         WRITE (6,5) (JM1,(A(I,J),I=1,3))
ISN   12       5 FORMAT (9X,'A',I2,8X,E10.4,5X,E10.4,3X,E10.4/)
ISN   13      12 CONTINUE
ISN   14         DO 14 J=1,4
ISN   15         WRITE (6,6) (J,(B(I,J),I=1,3))
ISN   16       6 FORMAT (9X,'B',I2,8X,E10.4,5X,E10.4,3X,E10.4/)
ISN   17      14 CONTINUE
          C      WRITE OUTPUT HEADINGS.
ISN   18         WRITE (6,7)
```

```
ISN  19      7 FORMAT ('1','OUTPUT DATA : '//)
ISN  20        WRITE (6,8)
ISN  21      8 FORMAT (8X,'DATE',13X,'DECLINATION',16X,'EQUATION OF TIME',5X,'RAD
              1IUS VECTOR'/)
          C
          C    READ IN DAYS OF INTEREST.
          C
ISN  22     20 READ(5,2) (D(I),I=1,6)
ISN  23      2 FORMAT (6F5.1)
          C
          C    CONVERT DAY OF YEAR TO ANGLE.
          C
ISN  24        DO 40 I=1,6
ISN  25        THETA=6.2832*D(I)/365.
          C
          C    CALCULATE COEFFICIENTS USING MULTIPLES OF 1 TO 4 ANGLES.
ISN  26        DO 30 J=1,4
ISN  27        SUM(J)=A(J,1)
ISN  28        DO 30 K=1,4
ISN  29        FACT=K
ISN  30        SUM(J)=(SIN(THETA*FACT))*A(J,K+1)+SUM(J)
ISN  31     30 SUM(J)=(COS(THETA*FACT))*B(J,K)+SUM(J)
          C
          C    PRINT AND PUNCH ESTIMATED SOLAR EPHEMERIC DATA.
ISN  32        WRITE (6,9) D(I),SUM(1),SUM(2),SUM(3)
ISN  33      9 FORMAT (2(5X,E10.4,5X),10X,2(5X,E10.4,5X))
ISN  34     40 WRITE(7,11) D(I),SUM(1),SUM(2),SUM(3)
ISN  35     11 FORMAT (2E10.4,10X,2E10.4)
ISN  36        IF(D(6).NE.0.) GO TO 20
ISN  37        STOP
ISN  38        END
```

```
C
C DATA REQUIRED FOR SOLAR EPHEMERIC DATA ESTIMATOR :
C REGRESSION COEFFICIENTS :
+.3964E-00+.3631E+01+.3838E-01+.7659E-01
-.2297E+02-.3885E-00-.1587E-00-.1021E-01
+.2733E-02-.7343E+01-.9470E+01-.3289E-00-.1935E-00
+.5519E-00-.3020E+01-.7581E-01-.1245E-00
+.1000E+01-.9464E-03                -.2917E-04
-.1671E-01-.1489E-03                -.3438E-04
C
C DAYS OF THE YEAR TO BE PROCESSED :
C
   1.    2.    3.    4.    5.    6.
   7.    8.    9.   10.   11.   12.
  13.   14.   15.   16.   17.   18.
  19.   20.   21.   22.   23.   24.
  25.   26.   27.   28.   29.   30.
  31.   32.   33.   34.   35.   36.
  37.   38.   39.   40.   41.   42.
  43.   44.   45.   46.   47.   48.
  49.   50.   51.   52.   53.   54.
  55.   56.   57.   58.   59.   60.
  61.   62.   63.   64.   65.   66.
  67.   68.   69.   70.   71.   72.
  73.   74.   75.   76.   77.   78.
  79.   80.   81.   82.   83.   84.
  85.   86.   87.   88.   89.   90.
  91.   92.   93.   94.   95.   96.
  97.   98.   99.  100.  101.  102.
 103.  104.  105.  106.  107.  108.
 109.  110.  111.  112.  113.  114.
 115.  116.  117.  118.  119.  120.
 121.  122.  123.  124.  125.  126.
```

127.	128.	129.	130.	131.	132.
133.	134.	135.	136.	137.	138.
139.	140.	141.	142.	143.	144.
145.	146.	147.	148.	149.	150.
151.	152.	153.	154.	155.	156.
157.	158.	159.	160.	161.	162.
163.	164.	165.	166.	167.	168.
169.	170.	171.	172.	173.	174.
175.	176.	177.	178.	179.	180.
181.	182.	183.	184.	185.	186.
187.	188.	189.	190.	191.	192.
193.	194.	195.	196.	197.	198.
199.	200.	201.	202.	203.	204.
205.	206.	207.	208.	209.	210.
211.	212.	213.	214.	215.	216.
217.	218.	219.	220.	221.	222.
223.	224.	225.	226.	227.	228.
229.	230.	231.	232.	233.	234.
235.	236.	237.	238.	239.	240.
241.	242.	243.	244.	245.	246.
247.	248.	249.	250.	251.	252.
253.	254.	255.	256.	257.	258.
259.	260.	261.	262.	263.	264.
265.	266.	267.	268.	269.	270.
271.	272.	273.	274.	275.	276.
277.	278.	279.	280.	281.	282.
283.	284.	285.	286.	287.	288.
289.	290.	291.	292.	293.	294.
295.	296.	297.	298.	299.	300.
301.	302.	303.	304.	305.	306.
307.	308.	309.	310.	311.	312.
313.	314.	315.	316.	317.	318.
319.	320.	321.	322.	323.	324.

```
325. 326. 327. 328. 329. 330.
331. 332. 333. 334. 335. 336.
337. 338. 339. 340. 341. 342.
343. 344. 345. 346. 347. 348.
349. 350. 351. 352. 353. 354.
355. 356. 357. 358. 359. 360.
361. 362. 363. 364. 365.     .
```

```
          C
          C      FORTRAN PROGRAM . ASTROMETEOROLOGICAL ESTIMATOR.
          C      ----------------------------------------------------
          C SOURCE: G.W. ROBERTSON AND D.A. RUSSELO, ASTROMETEOROLOGICAL
          C          ESTIMATOR, FORTRAN PROGRAM 1044-04-37, AG. MET. TECH.
          C          BULLETIN #14 (OTTAWA : AGROMETEOROLOGICAL SECTION, PLANT
          C          RESEARCH INSTITUTE, RESEARCH BRANCH, C.D.A., 1968).
          C
          C NOTE : THE SOLVING PROCEDURE IS THE SAME AS OUTLINED IN THE ABOVE
          C        REFERENCE EXCEPT FOR THE CHANGE IN INTEGRATION PROCEDURE.
          C        MOST OF THE I/O FORMATS HAVE BEEN ALTERED.
ISN    1         REAL*4 SOLTME,RRAD,TIMES,TTWO,TONE,DUMMY,SINPHI,COSPHI,SINDEL,COSD
               1EL,ENERGY,VALUE,TOTAL,TVEC,AVEC
ISN    2         INTEGER*4 PLUS,MINUS,NUMCAL
ISN    3         DIMENSION TVEC(6,6),AVEC(6,6)
ISN    4         DIMENSION  US(365),ENERGY(12),NUMCAL(12)
ISN    5         DIMENSION IS(31,12),JEARS(31,12),NAME(8),WISE(12),MONDAY(11),DCLNT
               1N(365),IR(31,12),OLAT(365),TITLE(5)
          C
          C      SIGNS THAT MAY BE USED ON RUN-CONTROL CARD(I-CARD-1)
ISN    6         DATA PLUS,MINUS/'+','-'/
          C      DAY OF THE YEAR CORRESPONDING TO THE LAST DAY OF THE MONTH.
ISN    7         DATA MONDAY/31,59,90,120,151,181,212,243,273,304,334/
          C
          C      FORMAT STATEMENTS.
          C
ISN    8    100 FORMAT (9X,I1)
ISN    9    101 FORMAT ('1',5X,'FORTRAN PROGRAM--ASTROMETEOROLOGICAL ESTIMATOR'/4X
               1,'DAY OF YEAR',7X,'SOLAR',9X,'EQUATION',7X,'RADIUS'/19X,'DECLINATI
               2ON',6X,'OF  TIME',7X,'VECTOR')
ISN   10    102 FORMAT(2E10.4,10X,2E10.4)
ISN   11    103 FORMAT (4(5X,E10.4))
ISN   12    104 FORMAT(1X,18HCARDS OUT OF ORDER )
```

```
ISN  13   105 FORMAT(9X,I1)
ISN  14   106 FORMAT(15X,F18.15,7X,F18.15)
ISN  15   107 FORMAT('1',/10X,'GAUSS QUADRATURE TABLE :')
ISN  16   108 FORMAT(/8X,'POINT',4X,'J',15X,'T(J)',21X,'A(J)'/)
ISN  17   109 FORMAT(9X,I1,7X,I1,7X,F18.15,7X,F18.15)
ISN  18   110 FORMAT('1',/5X,4A3,9A2,2I3,I5,I3,1X,A1,I2,I3,3I4,I3,2(I3,1X,I2),I2
             1)
ISN  19   111 FORMAT(4A3,9A2,2I3,I5,I3,1X,A1,I2,I3,3I4,I3,2(I3,1X,I2),I2)
ISN  20   112 FORMAT (1X,'SOLAR ENERGY',29X,'FOR HOUR ENDING'/85X,'DAILY'/17X,'D
             1AY    12    11    10     9     8     7',4X,'6     5     4     3     2     1',
             25X,'TOTAL'/18X,'NO    13    14    15    16    17    18    19',3X,'20    21
             3',3X,'22    23    24',5X,'ENERGY'/)
ISN  21   113 FORMAT(12HSOLAR ENERGY,24X,15HFOR HOUR ENDING /72X,5HDAILY/17X,40H
             1DAY  12  11  10   9   8   7   6   5   4 ,20H  3   2   1     TOTAL/
             218X,40HNO  13  14  15  16  17  18  19  20  21  ,20H22  23  24     E
             3NERGY/)
ISN  22   114 FORMAT (1X,8A2,13(I4,1X),F8.1)
ISN  23   115 FORMAT (8A2,13I4,F8.1)
ISN  24   116 FORMAT (1X,8A2,3X,I4,3X,F6.2)
ISN  25   117 FORMAT(8A2,3X,I4,3X,F6.2)
ISN  26   118 FORMAT(79X,1H+)
ISN  27   119 FORMAT('1',/33X,8A2,16X,15HSOLAR ELEVATION /)
ISN  28   120 FORMAT(32X,18HDAYLENGTH IN HOURS  ,20X,A1,2I3 //)
ISN  29   121 FORMAT(40H DATE      JAN    FEB    MAR    APR    MAY   J ,39HUNE   JULY
             1 AUG   SEPT    OCT    NOV    DEC   /)
ISN  30   122 FORMAT(1X,I4,2X,12F6.1)
ISN  31   123 FORMAT(I4,3X,12F6.1)
ISN  32   124 FORMAT(1X,8A2,14HTOTAL FROM DAY ,I4,3X,6HTO DAY ,I4,3X,2HBY,I4,2X,
             18HDAYS  IS ,F7.1,//)
ISN  33   125 FORMAT(8A2,14HTOTAL FROM DAY ,I4,3X,6HTO DAY ,I4,3X,2HBY,I4,2X,8HD
             1AYS  IS ,F7.1,//)
ISN  34   126 FORMAT(32X,15HTIME OF SUNRISE  ,23X,A1,2I3 //)
ISN  35   127 FORMAT(29X,20HIN HOURS AND MINUTES /   )
```

```
ISN  36  128 FORMAT (1X,I4,3X,12F6.2)
ISN  37  129 FORMAT(I4,3X,12F6.2)
ISN  38  130 FORMAT(32X,14HTIME OF SUNSET  ,24X,A1,2I3 //)
ISN  39  131 FORMAT (1X,28HSEPARATE OUTPUT, PRESS START )
         C
         C     LIST OF SOME VARIABLES USED IN THIS PROGRAM AND THEIR TERMS OF
         C     REFERENCE.
         C     NAME           QUANTITY OR QUANTITIES REFERRED TO
         C     ----           ----------------------------------
         C     LINES          NUMBER OF LINES PRINTED ON A GIVEN PAGE
         C     DAY            DAY OF THE YEAR                          (I-CARD-2)
         C     DCLN           SOLAR DECLINATION IN DECIMAL DEGREES(I-CARD-2)
         C     FLOAT          EQUATION OF TIME IN DECIMAL MINUTES (I-CARD-2)
         C     RAD            RADIUS VECTOR
         C     GLAT(I)        EQUATION OF TIME CORRESPONDING TO DAY I (IN MINUTES)
         C     US(I)          RADIUS VECTOR    CORRESPONDING TO DAY I
         C     DCLNTN(I)      SOLAR DECLINATION CORRESPONDING TO DAY I (IN RADIANS)
         C     NPT            POINTS OF GAUSSIAN QUADRATURE USED IN INTEGRATION
         C     TVEC           ZEROS  OF THE LEGENDRE POLYNOMIALS USED IN GAUSS SBR.
         C     AVEC           WEIGHTSOF THE LEGENDRE POLYNOMIALS USED IN GAUSS SBR.
         C     STALAT         STATION LATITUDE IN DECIMAL DEGREES THEN RADIANS
         C     STLONG         STATION LONGITUDE IN DECIMAL DEGREES THEN RADIANS
         C     ELEVTN         SOLAR ELEVATION IN DECIMAL DEGREES THEN RADIANS
         C     TIMESS         SOLAR SUNSET TIME IN MINUTES AFTER NOON
         C     SOLTME         SOLAR TIME IN MINUTES AFTER NOON
         C     ENERGY(I)      SOLAR ENERGY IN GM.-CAL./CM.**2 FOR HOUR I BEFORE OR
         C                    AFTER NOON
         C     NUMCAL(I)      ENERGY(I) TAKEN TO THE NEAREST 0.1 GM.-CAL./CM.**2
         C     TOTAL          TOTAL SOLAR ENERGY FOR DAY BEING ANALYZED
         C     IR(I,J)        LOCAL STANDARD TIME OF SUNRISE FOR DAY I OF MONTH J
         C     IS(I,J)        LOCAL STANDARD TIME OF SUNSET  FOR DAY I OF MONTH J
         C
         C     READ IN CARD ASKING FOR (0) PRINT AND PUNCH, (1) PRINT ONLY,
```

```
          C       OR (2) PUNCH ONLY, INDICATED IN COLUMN TEN.
ISN  40           READ (5,100) ICUT
ISN  41           IF(ICUT.EQ.2) GO TO 10
ISN  42           WRITE (6,101)
ISN  43           LINES=3
ISN  44        10 DO 15 I=1,365
ISN  45           IF(LINES.LT.60) GO TO 14
ISN  46           WRITE (6,101)
ISN  47           LINES=3
          C
          C       READ CONTROL CARDS-SOLAR EPHEMERIS DATA (I-CARD-2)
          C       THESE CARDS WERE GENERATED USING ROBERTSON AND RUSSELO'S PROGRAM
          C       1044-0431  ''SOLAR EPHEMERIC DATA ESTIMATOR''.
ISN  48        14 READ(5,102) DAY,DCLN,FLOAT,RAD
ISN  49           WRITE (6,103) DAY,DCLN,FLOAT,RAD
ISN  50           LINES=LINES+1
ISN  51           QUAT(I)=FLOAT
ISN  52           US(I)=RAD
ISN  53           DCLNIN(I)=DCLN/(57.+17.7/60.)
ISN  54           FLOAT=I
ISN  55           IF(FLOAT-DAY) 16,15,16
ISN  56        15 CONTINUE
ISN  57           GO TO 17
ISN  58        16 WRITE (6,104)
ISN  59           GO TO 14
          C       READ IN GAUSS QUADRATURE TABLE.
ISN  60        17 READ(5,105) NPT
ISN  61           DO 18  NPOINT=1,NPT
ISN  62           DO 18  J=1,NPOINT
ISN  63        18 READ(5,106) TVEC(NPOINT,J),AVEC(NPOINT,J)
ISN  64           WRITE (6,107)
ISN  65           WRITE (6,108)
ISN  66           DO  19 NPOINT=1,NPT
```

```
ISN  67        DO  19 J=1,NPOINT
ISN  68     19 WRITE (6,109) NPOINT,J,TVEC(NPOINT,J),AVEC(NPOINT,J)
       C       RESET SWITCHES AND CLEAR STORAGE AREAS.
ISN  69     20 DO 21 I=1,12
ISN  70        DO 21 J=1,31
ISN  71        IS(J,1)=0
ISN  72        IR(J,I)=0
ISN  73     21 JEARS(J,I)=0
ISN  74        SWICH1=0.0
ISN  75        SWICH2=0.0
ISN  76        SWICH3=0.0
ISN  77        SWICH4=0.0
ISN  78        SUML=0.0
       C
       C    DESCRIPTION OF VARIABLES ON RUN-CONTROL CARD(I-CARD-1).
       C       COLUMNS NAME    DESCRIPTION OR EXPLANATION
       C       ------- ----    --------------------------
       C          1-13 TITLE   JOB AND PROGRAM NUMBER
       C         15-30 NAME    STATION IDENTIFICATION IN ALPHA-NUMERIC
       C         31            SIGN OF STATION LATITUDE  ;N=+;S=-
       C         32-33 LATSTA  STATION LATITUDE; WHOLE DEGREES
       C         35-36 LATDEC  STATION LATITUDE; WHOLE MINUTES
       C         38            SIGN OF STATION LONGITUDE ;W=+;E=-
       C         39-41 LONGST  STATION LONGITUDE; WHOLE DEGREES
       C         43-44 LONGDC  STATION LONGITUDE; WHOLE MINUTES
       C         46    A       SIGN OF SOLAR ELEVATION; ABOVE HORIZON=+
       C                                                BELOW HORIZON=-
       C         47-48 IELIVT  SOLAR ELEVATION; WHOLE DEGREES
       C         50-51 IELI    SOLAR ELEVATION; WHOLE MINUTES
       C         53-55 IZNACT  MERIDIAN OF STANDARD TIME ZONE; WHOLE DEGREES
       C         57-59 IFIRST  DAY OF YEAR FOR BEGINNING CALCULATIONS; JAN.1=001
       C         61-63 LAST    DAY OF YEAR FOR  ENDING   CALCULATIONS; DEC.31=365
       C         65-66 JUMP    INCREMENT IN WHOLE DAYS FOR CALCULATIONS
```

```
      C        68-69 MIN     BEGINNING DATE FOR ACCUMULATION; DAY OF MONTH
      C        70            BLANK,SLASH OR DASH
      C        71-72 MINMON  BEGINNING DATE FOR ACCUMULATION; MONTH NUMBER
      C        74-75 MAX     ENDING DATE FOR ACCUMULATION; DAY OF MONTH
      C        76            BLANK,SLASH OR DASH
      C        77-78 MAXMON  ENDING DATE FOR ACCUMULATION; MONTH NUMBER
      C        80     IBOSS  CODE FOR TABLE OUTPUT:
      C                      1 - LIST OF DAYLENGTHS ONLY
      C                      2 - TABLE OF DAYLENGTHS ONLY
      C                      3 - BOTH LIST AND TABLE
      C                      4 - TABLES OF TIMES ONLY
      C                      5 - TABLES OF DAYLENGTH AND TIMES
      C                      6 - LIST AND ALL TABLES
      C                      7 - CALCULATE AND LIST SOLAR RADIATION(QO)
      C      READ RUN-CONTROL CARD (I-CARD-1)
ISN  79      READ (5,111,END=208) TITLE,NAME,LATSTA,LATDEC,LONGST,LONGDC,A,IELI
            1VT,IELI,IZNACT,IFIRST,LAST,JUMP,MIN,MINMON,MAX,MAXMON,IBOSS
      C      PUNCH RUN-CONTROL CARD FOR IDENTIFICATION (TABLE-3)
ISN  80      IF(ICUT.GT.1) GO TO 22
ISN  81      WRITE(6,110) TITLE,NAME,LATSTA,LATDEC,LONGST,LONGDC,A,IELIVT,IELI,
            1IZNACT,IFIRST,LAST,JUMP,MIN,MINMON,MAX,MAXMON,IBOSS
ISN  82      IF(ICUT.EQ.1) GO TO 23
ISN  83   22 WRITE(7,111) TITLE,NAME,LATSTA,LATDEC,LONGST,LONGDC,A,IELIVT,IELI,
            1IZNACT,IFIRST,LAST,JUMP,MIN,MINMON,MAX,MAXMON,IBOSS
ISN  84      WRITE (7,111)
      C      INITIALIZING CONSTANTS FOR RUN.
      C      FIRST TWO CARDS MAKE ALLOWANCE FOR EAST LONGITUDE AND SOUTH
      C      LATITUDE.
ISN  85   23 IF(LATSTA.LT.0) LATDEC=LATDEC*(-1.0)
ISN  86      IF(LONGST.LT.0) LONGDC=LONGDC*(-1.0)
ISN  87      STALAT=LATSTA+LATDEC/60.
ISN  88      STLONG=LONGST+LONGDC/60.
ISN  89      SITN=1.0
```

```
ISN  90        IF(A.EQ.PLUS) GO TO 25
ISN  91     24 SITN=-1.
ISN  92     25 ELEVTN=(IELIVT+IELI/60.)*SITN
ISN  93        IF(MINMON-1) 27,27,26
ISN  94     26 MIN=MONDAY(MINMON-1)+MIN
ISN  95     27 IF(MAXMON-1) 29,29,28
ISN  96     28 MAX=MONDAY(MAXMON-1)+MAX
          C    SELECTION OF COMBINATIONS FOR OUTPUT AND SETTING OF SWITCHES.
ISN  97     29 GO TO (31,32,30,38,37,36,33),IBOSS
ISN  98     30 SWICH2=1
ISN  99     31 SWICH1=1
ISN 100        GO TO 39
ISN 101     32 SWICH2=1
ISN 102        GO TO 39
ISN 103     33 SWICH3=1
          C    HEADING FOR TABLE-4.
ISN 104        IF(ICUT.GT.1) GO TO 34
ISN 105        WRITE (6,112)
ISN 106        IF(ICUT.EQ.1) GO TO 35
ISN 107     34 WRITE (7,113)
ISN 108     35 GO TO 39
ISN 109     36 SWICH1=1
ISN 110     37 SWICH2=1
ISN 111     38 SWICH4=1
ISN 112     39 ELEVTN=ELEVTN/(57.+17.7/60.)
ISN 113        STALAT=STALAT/(57.+17.7/60.)
          C    DAILY CALCULATIONS OF DAYLENGTH.
ISN 114        EICM=4.0*(STLONG-IZNACT)/60.
ISN 115        DO 74 IDAY= IFIRST,LAST,JUMP
ISN 116        DECLIN=DCLNTN(IDAY)
ISN 117        CALA=SIN(STALAT)
ISN 118        CALE=SIN(DECLIN)
ISN 119        EIGA=CALA*CALE
```

```
      CALB=SIN(ELEVTN)
      CALA=CALB-BIGA
      CALB=COS(STALAT)
      CALC=COS(DECLIN)
      BIGB=CALB*CALC
      CALA=CALA/BIGB
      IF(CALA+1.) 40,40,41
   40 HOURS=0.0
      GO TO 45
   41 IF(CALA-1.) 43,42,42
   42 HOURS=24.0
      GO TO 45
   43 HOURS=ARCOS(CALA)
      HOURS=HOURS*7.639
      IF(HOURS)44,45,45
   44 HOURS=HOURS+24.0
   45 FLOAT=HOURS
      IF(SWICH3)53,53,46
C     CALCULATE SOLAR TIME OF SUNSET.
   46 TRUESS=0.5*FLOAT+12.0
      DO  47 IUSE=1,12
C     CALCULATE HOURLY ENERGY.
   47 ENERGY(IUSE)=0.0
      SINPHI=SIN(STALAT)
      COSPHI=COS(STALAT)
      SINDEL=SIN(DECLIN)
      COSDEL=COS(DECLIN)
      TOTAL =0.0
      NUMBER=1
C     SOLTME = SOLAR TIME AT END OF HOURLY INTERVAL(MINUTES AFTER NOON)
      SOLTME=0.0
      REAL=US(IDAY)
C     TIMESS IS SOLAR TIME IN MINUTES AFTER NOON OF SUNSET.
```

```
ISN 149          TIMESS=60.0*(TRUESS-12.)
ISN 150          NPOINT=6
ISN 151       48 SOLTME=SOLTME+60.0
ISN 152          IF(TIMESS-SOLTME) 50,50,49
ISN 153       49 TTWO=SOLTME
ISN 154          TONE=SOLTME-60.0
ISN 155          CALL GAUSS (TONE,TTWO,RRAD,SINPHI,SINDEL,COSPHI,COSDEL,TVEC,AVEC,N
                1POINT,VALUE)
ISN 156          ENERGY(NUMBER)=VALUE
ISN 157          TOTAL=TOTAL+ENERGY(NUMBER)*2.
ISN 158          NUMBER =NUMBER+1
ISN 159          GO TO 48
         C       ENERGY IN FRACTIONAL PERIODS ENDING AFTER AND BEFORE ZT=0. WHERE
         C       ZT IS SOLAR ZENITH ANGLE AT BEGINNING OF HOURLY INTERVAL.
ISN 160       50 TONE=SOLTME-60.0
ISN 161          TTWO=TIMESS
ISN 162          CALL GAUSS (TONE,TTWO,RRAD,SINPHI,SINDEL,COSPHI,COSDEL,TVEC,AVEC,N
                1POINT,VALUE)
ISN 163          ENERGY(NUMBER)=VALUE
ISN 164          TOTAL=TOTAL+ENERGY(NUMBER)*2.
ISN 165          IFIX=FLOAT*10.+.5
ISN 166          FL=IFIX
ISN 167          FL=FL*.1
ISN 168          DO 51  M=1,12
ISN 169          ENERGY(M)=ENERGY(M)*10.+.5
ISN 170       51 NUMCAL(M)=ENERGY(M)
ISN 171          TOTAL=TOTAL+.05
         C       PUNCH HOURLY AND DAILY ENERGY (QO) (TABLE-4)
ISN 172          IF(IOUT.GT.1) GO TO 52
ISN 173          WRITE (6,114) NAME,IDAY,(NUMCAL(K),K=1,12),TOTAL
ISN 174          IF(IOUT.EQ.1) GO TO 53
ISN 175       52 WRITE (7,115) NAME,IDAY,(NUMCAL(K),K=1,12),TOTAL
ISN 176       53 IFIX=HOURS*10.+.5
```

```
ISN 177        HOURS=IFIX
ISN 178        HOURS=HOURS/10.
ISN 179     54 IF(IDAY-MAX)55,55,57
ISN 180     55 IF(IDAY-MIN)57,57,56
ISN 181     56 SUML=HOURS+SUML
          C    PUNCH DAYLENGTH LIST (TABLE-5)
ISN 182     57 IF(SWICH1)  60,60,58
ISN 183     58 IF(IOUT.GT.1) GO TO 59
ISN 184        WRITE (6,116) NAME,IDAY,FLOAT
ISN 185        IF(IOUT.EQ.1) GO TO 60
ISN 186     59 WRITE(7,117) NAME,IDAY,FLOAT
ISN 187     60 DO 61 I=1,11
ISN 188        IF(IDAY-MONDAY(I))62,62,61
ISN 189     61 CONTINUE
ISN 190        GO TO 64
ISN 191     62 IF(I-1)64,63,64
ISN 192     63 IDENT=IDAY
ISN 193        GO TO  65
ISN 194     64 IDENT=IDAY-MONDAY(I-1)
ISN 195     65 JEARS(IDENT,I)=HOURS*10.
          C    CALCULATE LOCAL STANDARD TIME OF SUNRISE AND SUNSET.
ISN 196        IF(SWICH4)74,74,66
ISN 197     66 IF(HOURS) 74,74,67
ISN 198     67 IF(HOURS-24.0)68,74,74
ISN 199     68 EQUAT=QUAT(IDAY)
ISN 200        CALA=12.-EQUAT*000.01667+BIGM
ISN 201        CALB=0.5*FLOAT
ISN 202        CALC=CALA-CALB
ISN 203        IFIX=CALC
ISN 204        FLOAT=IFIX
ISN 205        IF(CALC-FLOAT-.91666)70,70,69
ISN 206     69 IR(IDENT,I)=(FLOAT+1.)*100.0
ISN 207        GO TO 71
```

```
ISN 208    70 IS(ICENT,I)=(((CALC-FLOAT)*0.600)+FLOAT+.005)*100.
ISN 209    71 CALC=CALA+CALB
ISN 210       IFIX=CALC
ISN 211       FLOAT=IFIX
ISN 212       IF(CALC-FLOAT-.991666)73,73,72
ISN 213    72 IS(ICENT,I)=(FLOAT+1.)*100.0
ISN 214       GO TO 74
ISN 215    73 IS(ICENT,I)=(((CALC-FLOAT)*0.600)+FLOAT+0.005)*100.
ISN 216    74 CONTINUE
          C   PUNCH DAYLENGTH TABLE (TABLE-6)
ISN 217       IF(SWICH2)84,84,75
ISN 218    75 K=5
ISN 219       IF(ICUT.GT.1) GO TO 76
ISN 220       WRITE (6,118)
ISN 221       WRITE (6,119) NAME
ISN 222       WRITE (6,120) A,IELIVT,IELI
ISN 223       WRITE (6,121)
ISN 224       IF(ICUT.EQ.1) GO TO 77
ISN 225    76 WRITE(7,118)
ISN 226       WRITE(7,119) NAME
ISN 227       WRITE(7,120) A,IELIVT,IELI
ISN 228       WRITE(7,121)
ISN 229    77 DO 83  I=1,31
ISN 230       DO 78  J=1,12
ISN 231       FLOAT=JEARS(I,J)
ISN 232    78 WISE(J)=FLOAT*.1
ISN 233       IF(ICUT.GT.1) GO TO 79
ISN 234       WRITE (6,122) I,WISE
ISN 235       IF(ICUT.EQ.1) GO TO 80
ISN 236    79 WRITE(7,123) I,WISE
ISN 237    80 IF(I-K)83,81,83
ISN 238    81 K=K+5
ISN 239       IF(ICUT.GT.1) GO TO 82
```

```
      WRITE (6,124)
      IF(ICUT.EQ.1) GO TO 83
   82 WRITE(7,125)
   83 CONTINUE
C     PUNCH SUNRISE AND SUNSET TABLES (TABLE-7)
   84 IF(SWICH4)202,202,85
   85 K=5
      IF(ICUT.GT.1) GO TO 86
      WRITE(6,118)
      WRITE(6,119) NAME
      WRITE(6,126) A,IELIVT,IELI
      WRITE(6,127)
      WRITE(6,121)
      IF(ICUT.EQ.1) GO TO 87
   86 WRITE(7,118)
      WRITE(7,119) NAME
      WRITE(7,126) A,IELIVT,IELI
      WRITE(7,127)
      WRITE(7,121)
   87 DO 93  I=1,31
      DO 88  J=1,12
      FLOAT=IR(I,J)
   88 WISE(J)=FLOAT*.01
      IF(ICUT.GT.1) GO TO 89
      WRITE (6,128) I,WISE
      IF(ICUT.EQ.1) GO TO 90
   89 WRITE(7,129) I,WISE
   90 IF(I-K) 93,91,93
   91 K=K+5
      IF(ICUT.GT.1) GO TO 92
      WRITE (6,124)
      IF(ICUT.EQ.1) GO TO 93
   92 WRITE(7,125)
```

```
 93 CCNTINLE
    IF(ICLT.GT.1) GC TC 94
    WRITE (6,118)
    K=5
    WRITE (6,119) NAME
    WRITE (6,130) A,IELIVT,IELI
    WRITE (6,127)
    WRITE (6,121)
    IF(ICLT.EQ.1) GC TC 95
 94 WRITE(7,118)
    K=5
    WRITE(7,119) NAME
    WRITE(7,130) A,IELIVT,IELI
    WRITE(7,127)
    WRITE(7,121)
 95 DC 201 I=1,31
    DC  96 J=1,12
    FLCAT=IS(I,J)
 96 WISE(J)=FLCAT*.01
    IF(ICLT.GT.1) GC TC 97
    WRITE (6,128) I,WISE
    IF(ICLT.EQ.1) GO TO 98
 97 WRITE(7,129) I,WISE
 98 IF(I-K) 201,99,201
 99 K=K+5
    IF(ICLT.GT.1) GC TC 200
    WRITE (6,124)
    IF(ICLT.EQ.1) GC TL 201
200 WRITE (7,125)
201 CCNTINLE
202 IF(MIN)205,205,203
203 IF(ICLT.GT.1) GC TC 204
    WRITE (6,118)
```

```
ISN 305         WRITE (6,124) NAME,MIN,MAX,JUMP,SUML
ISN 306         IF(ICUT.EQ.1) GO TO 205
ISN 307     204 WRITE (7,118)
          C     PUNCH ACCUMULATED HOURS OF DAYLENGTH (TABLE-8)
ISN 308         WRITE (7,125) NAME,MIN,MAX,JUMP,SUML
ISN 309     205 IF(ICUT.GT.1) GO TO 206
ISN 310         IF(ICUT.EQ.1) GO TO 207
ISN 311     206 WRITE (7,131)
ISN 312     207 GO TO 20
ISN 313     208 CONTINUE
ISN 314         STOP
ISN 315         END


ISN   1         SUBROUTINE GAUSS(A,B,R,SINP,SIND,COSP,COSD,TVEC,AVEC,N,INTGRL)
          C
          C     INTEGRATION SUBROUTINE USING GAUSSIAN QUADRATURE METHOD.
          C
          C  REFERENCE: S.D. CONTE, ELEMENTARY NUMERICAL ANALYSIS ( NEW YORK :
          C             MCGRAW-HILL BOOK COMPANY,INC., 1965) 138-142.
          C    NOTE: NO DIFFERENCE IN ANSWERS WERE NOTED WHEN 5 AND 6 POINT
          C             GAUSSIAN QUADRATURE WERE COMPARED.
          C
ISN   2         IMPLICIT REAL*4(A-H,O-Z),INTEGER*4(I-N)
ISN   3         REAL*4 INTGRL,JO
ISN   4         DIMENSION TVEC(6,6),AVEC(6,6)
ISN   5         FCN(SINP,SIND,COSP,COSD,F,JO,R)=(SINP*SIND+COSP*COSD* COS(F))*JO/R
               1**2
ISN   6         SUM=0.
ISN   7         JO=1.94
ISN   8         DO 999 J=1,N
ISN   9         X=0.5*(B-A)*TVEC(N,J)+0.5*(A+B)
ISN  10         IF(X.NE.0) GO TO 990
```

```
ISN  11         F=15.
ISN  12         GO TO 995
ISN  13    990  F=15.*X/(60.*57.+17.7)
ISN  14    995  SUM=SUM+AVEC(N,J)*FCN(SINP,SIND,COSP,COSD,F,JC,R)
ISN  15    999  CONTINUE
ISN  16         INTGRL=0.5*(B-A)*SUM
ISN  17         RETURN
ISN  18         END
```

```
C
C DATA  REQUIRED FOR ASTROMETEOROLOGICAL ESTIMATOR :
C INPUT/OUTPUT CARD :
          1
C
C OUTPUT OF THE SOLAR EPHEMERIC DATA ESTIMATOR PROGRAM.
0.1000E 01-.2306E 02           -.3146E 010.9831E 00
0.2000E 01-.2298E 02           -.3622E 010.9831E 00
0.3000E 01-.2289E 02           -.4093E 010.9831E 00
0.4000E 01-.2280E 02           -.4557E 010.9831E 00
0.5000E 01-.2270E 02           -.5016E 010.9831E 00
0.6000E 01-.2259E 02           -.5468E 010.9831E 00
0.7000E 01-.2247E 02           -.5912E 010.9831E 00
0.8000E 01-.2234E 02           -.6349E 010.9831E 00
0.9000E 01-.2221E 02           -.6778E 010.9832E 00
0.1000E 02-.2207E 02           -.7198E 010.9832E 00
0.1100E 02-.2193E 02           -.7609E 010.9832E 00
0.1200E 02-.2177E 02           -.8011E 010.9833E 00
0.1300E 02-.2161E 02           -.8402E 010.9833E 00
0.1400E 02-.2144E 02           -.8784E 010.9834E 00
0.1500E 02-.2127E 02           -.9155E 010.9834E 00
0.1600E 02-.2109E 02           -.9515E 010.9835E 00
0.1700E 02-.2090E 02           -.9864E 010.9836E 00
0.1800E 02-.2070E 02           -.1020E 020.9836E 00
0.1900E 02-.2050E 02           -.1053E 020.9837E 00
0.2000E 02-.2029E 02           -.1084E 020.9838E 00
0.2100E 02-.2008E 02           -.1114E 020.9839E 00
0.2200E 02-.1986E 02           -.1143E 020.9840E 00
0.2300E 02-.1963E 02           -.1171E 020.9841E 00
0.2400E 02-.1940E 02           -.1197E 020.9842E 00
0.2500E 02-.1916E 02           -.1222E 020.9843E 00
0.2600E 02-.1891E 02           -.1246E 020.9844E 00
0.2700E 02-.1866E 02           -.1268E 020.9845E 00
```

0.2800E 02-.1840E 02	-.1289E 020.9847E 00
0.2900E 02-.1814E 02	-.1308E 020.9848E 00
0.3000E 02-.1787E 02	-.1326E 020.9849E 00
0.3100E 02-.1760E 02	-.1343E 020.9850E 00
0.3200E 02-.1732E 02	-.1359E 020.9852E 00
0.3300E 02-.1704E 02	-.1373E 020.9853E 00
0.3400E 02-.1675E 02	-.1385E 020.9855E 00
0.3500E 02-.1646E 02	-.1397E 020.9856E 00
0.3600E 02-.1616E 02	-.1406E 020.9858E 00
0.3700E 02-.1585E 02	-.1415E 020.9860E 00
0.3800E 02-.1555E 02	-.1422E 020.9861E 00
0.3900E 02-.1523E 02	-.1428E 020.9863E 00
0.4000E 02-.1492E 02	-.1432E 020.9865E 00
0.4100E 02-.1460E 02	-.1435E 020.9867E 00
0.4200E 02-.1427E 02	-.1437E 020.9868E 00
0.4300E 02-.1394E 02	-.1437E 020.9870E 00
0.4400E 02-.1361E 02	-.1437E 020.9872E 00
0.4500E 02-.1328E 02	-.1434E 020.9874E 00
0.4600E 02-.1294E 02	-.1431E 020.9876E 00
0.4700E 02-.1259E 02	-.1426E 020.9878E 00
0.4800E 02-.1225E 02	-.1420E 020.9880E 00
0.4900E 02-.1190E 02	-.1413E 020.9882E 00
0.5000E 02-.1154E 02	-.1405E 020.9884E 00
0.5100E 02-.1119E 02	-.1395E 020.9886E 00
0.5200E 02-.1083E 02	-.1385E 020.9889E 00
0.5300E 02-.1047E 02	-.1373E 020.9891E 00
0.5400E 02-.1010E 02	-.1360E 020.9893E 00
0.5500E 02-.9736E 01	-.1347E 020.9895E 00
0.5600E 02-.9367E 01	-.1332E 020.9898E 00
0.5700E 02-.8996E 01	-.1316E 020.9900E 00
0.5800E 02-.8622E 01	-.1299E 020.9902E 00
0.5900E 02-.8246E 01	-.1281E 020.9905E 00
0.6000E 02-.7869E 01	-.1263E 020.9907E 00

0.6100E 02-.7489E 01	-.1243E 020.9910E 00
0.6200E 02-.7108E 01	-.1223E 020.9912E 00
0.6300E 02-.6725E 01	-.1202E 020.9915E 00
0.6400E 02-.6341E 01	-.1180E 020.9917E 00
0.6500E 02-.5955E 01	-.1157E 020.9920E 00
0.6600E 02-.5568E 01	-.1134E 020.9922E 00
0.6700E 02-.5180E 01	-.1110E 020.9925E 00
0.6800E 02-.4791E 01	-.1085E 020.9927E 00
0.6900E 02-.4400E 01	-.1060E 020.9930E 00
0.7000E 02-.4009E 01	-.1034E 020.9933E 00
0.7100E 02-.3617E 01	-.1008E 020.9935E 00
0.7200E 02-.3225E 01	-.9807E 010.9938E 00
0.7300E 02-.2831E 01	-.9533E 010.9941E 00
0.7400E 02-.2438E 01	-.9255E 010.9943E 00
0.7500E 02-.2044E 01	-.8973E 010.9946E 00
0.7600E 02-.1649E 01	-.8687E 010.9949E 00
0.7700E 02-.1255E 01	-.8398E 010.9952E 00
0.7800E 02-.8601E 00	-.8106E 010.9954E 00
0.7900E 02-.4655E 00	-.7811E 010.9957E 00
0.8000E 02-.7105E-01	-.7514E 010.9960E 00
0.8100E 020.3232E 00	-.7215E 010.9963E 00
0.8200E 020.7171E 00	-.6915E 010.9966E 00
0.8300E 020.1111E 01	-.6613E 010.9968E 00
0.8400E 020.1504E 01	-.6310E 010.9971E 00
0.8500E 020.1896E 01	-.6007E 010.9974E 00
0.8600E 020.2288E 01	-.5703E 010.9977E 00
0.8700E 020.2679E 01	-.5399E 010.9980E 00
0.8800E 020.3069E 01	-.5096E 010.9983E 00
0.8900E 020.3458E 01	-.4793E 010.9986E 00
0.9000E 020.3846E 01	-.4491E 010.9988E 00
0.9100E 020.4233E 01	-.4191E 010.9991E 00
0.9200E 020.4618E 01	-.3892E 010.9994E 00
0.9300E 020.5002E 01	-.3595E 010.9997E 00

0.9400E 020.5385E 01	-.3300E 010.1000E 01
0.9500E 020.5766E 01	-.3008E 010.1000E 01
0.9600E 020.6146E 01	-.2719E 010.1001E 01
0.9700E 020.6524E 01	-.2432E 010.1001E 01
0.9800E 020.6900E 01	-.2150E 010.1001E 01
0.9900E 020.7274E 01	-.1871E 010.1001E 01
0.1000E 030.7646E 01	-.1595E 010.1002E 01
0.1010E 030.8016E 01	-.1325E 010.1002E 01
0.1020E 030.8384E 01	-.1058E 010.1002E 01
0.1030E 030.8749E 01	-.7968E 000.1003E 01
0.1040E 030.9113E 01	-.5404E 000.1003E 01
0.1050E 030.9473E 01	-.2894E 000.1003E 01
0.1060E 030.9831E 01	-.4390E-010.1003E 01
0.1070E 030.1019E 02	0.1957E 000.1004E 01
0.1080E 030.1054E 02	0.4293E 000.1004E 01
0.1090E 030.1089E 02	0.6565E 000.1004E 01
0.1100E 030.1124E 02	0.8772E 000.1005E 01
0.1110E 030.1158E 02	0.1091E 010.1005E 01
0.1120E 030.1192E 02	0.1298E 010.1005E 01
0.1130E 030.1226E 02	0.1498E 010.1005E 01
0.1140E 030.1259E 02	0.1690E 010.1006E 01
0.1150E 030.1292E 02	0.1874E 010.1006E 01
0.1160E 030.1325E 02	0.2051E 010.1006E 01
0.1170E 030.1357E 02	0.2220E 010.1006E 01
0.1180E 030.1389E 02	0.2381E 010.1007E 01
0.1190E 030.1421E 02	0.2533E 010.1007E 01
0.1200E 030.1452E 02	0.2677E 010.1007E 01
0.1210E 030.1483E 02	0.2812E 010.1007E 01
0.1220E 030.1513E 02	0.2939E 010.1008E 01
0.1230E 030.1543E 02	0.3057E 010.1008E 01
0.1240E 030.1573E 02	0.3165E 010.1008E 01
0.1250E 030.1602E 02	0.3265E 010.1008E 01
0.1260E 030.1631E 02	0.3355E 010.1009E 01

0.1270E 030.1659E 02	0.3436E 010.1009E 01
0.1280E 030.1687E 02	0.3508E 010.1009E 01
0.1290E 030.1714E 02	0.3570E 010.1009E 01
0.1300E 030.1741E 02	0.3623E 010.1010E 01
0.1310E 030.1767E 02	0.3666E 010.1010E 01
0.1320E 030.1793E 02	0.3700E 010.1010E 01
0.1330E 030.1819E 02	0.3724E 010.1010E 01
0.1340E 030.1843E 02	0.3739E 010.1011E 01
0.1350E 030.1868E 02	0.3744E 010.1011E 01
0.1360E 030.1892E 02	0.3740E 010.1011E 01
0.1370E 030.1915E 02	0.3726E 010.1011E 01
0.1380E 030.1938E 02	0.3703E 010.1011E 01
0.1390E 030.1960E 02	0.3671E 010.1012E 01
0.1400E 030.1981E 02	0.3629E 010.1012E 01
0.1410E 030.2002E 02	0.3578E 010.1012E 01
0.1420E 030.2023E 02	0.3519E 010.1012E 01
0.1430E 030.2043E 02	0.3450E 010.1012E 01
0.1440E 030.2062E 02	0.3372E 010.1013E 01
0.1450E 030.2081E 02	0.3286E 010.1013E 01
0.1460E 030.2099E 02	0.3192E 010.1013E 01
0.1470E 030.2116E 02	0.3089E 010.1013E 01
0.1480E 030.2133E 02	0.2978E 010.1013E 01
0.1490E 030.2150E 02	0.2859E 010.1013E 01
0.1500E 030.2165E 02	0.2733E 010.1014E 01
0.1510E 030.2180E 02	0.2599E 010.1014E 01
0.1520E 030.2195E 02	0.2457E 010.1014E 01
0.1530E 030.2208E 02	0.2309E 010.1014E 01
0.1540E 030.2222E 02	0.2155E 010.1014E 01
0.1550E 030.2234E 02	0.1994E 010.1014E 01
0.1560E 030.2246E 02	0.1826E 010.1014E 01
0.1570E 030.2257E 02	0.1653E 010.1015E 01
0.1580E 030.2267E 02	0.1475E 010.1015E 01
0.1590E 030.2277E 02	0.1291E 010.1015E 01

```
0.1600E 030.2286E 02          0.1103E 010.1015E 01
0.1610E 030.2295E 02          0.9098E 000.1015E 01
0.1620E 030.2303E 02          0.7127E 000.1015E 01
0.1630E 030.2310E 02          0.5118E 000.1015E 01
0.1640E 030.2316E 02          0.3074E 000.1015E 01
0.1650E 030.2322E 02          0.9995E-010.1016E 01
0.1660E 030.2327E 02          -.1102E 000.1016E 01
0.1670E 030.2332E 02          -.3226E 000.1016E 01
0.1680E 030.2335E 02          -.5370E 000.1016E 01
0.1690E 030.2339E 02          -.7529E 000.1016E 01
0.1700E 030.2341E 02          -.9700E 000.1016E 01
0.1710E 030.2343E 02          -.1188E 010.1016E 01
0.1720E 030.2344E 02          -.1406E 010.1016E 01
0.1730E 030.2344E 02          -.1624E 010.1016E 01
0.1740E 030.2343E 02          -.1842E 010.1016E 01
0.1750E 030.2342E 02          -.2058E 010.1016E 01
0.1760E 030.2341E 02          -.2274E 010.1016E 01
0.1770E 030.2338E 02          -.2488E 010.1016E 01
0.1780E 030.2335E 02          -.2700E 010.1016E 01
0.1790E 030.2331E 02          -.2909E 010.1016E 01
0.1800E 030.2327E 02          -.3116E 010.1016E 01
0.1810E 030.2322E 02          -.3320E 010.1016E 01
0.1820E 030.2316E 02          -.3519E 010.1017E 01
0.1830E 030.2309E 02          -.3715E 010.1017E 01
0.1840E 030.2302E 02          -.3907E 010.1017E 01
0.1850E 030.2294E 02          -.4094E 010.1017E 01
0.1860E 030.2286E 02          -.4276E 010.1017E 01
0.1870E 030.2277E 02          -.4453E 010.1017E 01
0.1880E 030.2267E 02          -.4623E 010.1017E 01
0.1890E 030.2256E 02          -.4788E 010.1017E 01
0.1900E 030.2245E 02          -.4947E 010.1017E 01
0.1910E 030.2233E 02          -.5099E 010.1017E 01
0.1920E 030.2221E 02          -.5243E 010.1016E 01
```

0.1930E 030.2208E 02	-.5381E 010.1016E 01
0.1940E 030.2194E 02	-.5511E 010.1016E 01
0.1950E 030.2180E 02	-.5634E 010.1016E 01
0.1960E 030.2165E 02	-.5748E 010.1016E 01
0.1970E 030.2149E 02	-.5854E 010.1016E 01
0.1980E 030.2133E 02	-.5952E 010.1016E 01
0.1990E 030.2116E 02	-.6040E 010.1016E 01
0.2000E 030.2099E 02	-.6120E 010.1016E 01
0.2010E 030.2081E 02	-.6191E 010.1016E 01
0.2020E 030.2063E 02	-.6253E 010.1016E 01
0.2030E 030.2043E 02	-.6305E 010.1016E 01
0.2040E 030.2024E 02	-.6348E 010.1016E 01
0.2050E 030.2004E 02	-.6381E 010.1016E 01
0.2060E 030.1983E 02	-.6404E 010.1016E 01
0.2070E 030.1961E 02	-.6418E 010.1016E 01
0.2080E 030.1939E 02	-.6421E 010.1015E 01
0.2090E 030.1917E 02	-.6415E 010.1015E 01
0.2100E 030.1894E 02	-.6398E 010.1015E 01
0.2110E 030.1871E 02	-.6371E 010.1015E 01
0.2120E 030.1847E 02	-.6334E 010.1015E 01
0.2130E 030.1822E 02	-.6287E 010.1015E 01
0.2140E 030.1797E 02	-.6230E 010.1015E 01
0.2150E 030.1772E 02	-.6162E 010.1015E 01
0.2160E 030.1746E 02	-.6084E 010.1015E 01
0.2170E 030.1719E 02	-.5997E 010.1014E 01
0.2180E 030.1692E 02	-.5899E 010.1014E 01
0.2190E 030.1665E 02	-.5791E 010.1014E 01
0.2200E 030.1637E 02	-.5673E 010.1014E 01
0.2210E 030.1609E 02	-.5546E 010.1014E 01
0.2220E 030.1580E 02	-.5408E 010.1014E 01
0.2230E 030.1551E 02	-.5261E 010.1013E 01
0.2240E 030.1521E 02	-.5105E 010.1013E 01
0.2250E 030.1491E 02	-.4939E 010.1013E 01

0.2260E 030.1461E 02	-.4764E 010.1013E 01
0.2270E 030.1430E 02	-.4580E 010.1013E 01
0.2280E 030.1399E 02	-.4386E 010.1013E 01
0.2290E 030.1368E 02	-.4185E 010.1012E 01
0.2300E 030.1336E 02	-.3974E 010.1012E 01
0.2310E 030.1304E 02	-.3755E 010.1012E 01
0.2320E 030.1271E 02	-.3528E 010.1012E 01
0.2330E 030.1238E 02	-.3293E 010.1012E 01
0.2340E 030.1205E 02	-.3050E 010.1011E 01
0.2350E 030.1172E 02	-.2800E 010.1011E 01
0.2360E 030.1138E 02	-.2542E 010.1011E 01
0.2370E 030.1104E 02	-.2277E 010.1011E 01
0.2380E 030.1069E 02	-.2006E 010.1011E 01
0.2390E 030.1034E 02	-.1727E 010.1010E 01
0.2400E 030.9995E 01	-.1443E 010.1010E 01
0.2410E 030.9643E 01	-.1152E 010.1010E 01
0.2420E 030.9288E 01	-.8553E 000.1010E 01
0.2430E 030.8930E 01	-.5530E 000.1009E 01
0.2440E 030.8570E 01	-.2454E 000.1009E 01
0.2450E 030.8208E 01	0.6723E-010.1009E 01
0.2460E 030.7844E 01	0.3847E 000.1009E 01
0.2470E 030.7478E 01	0.7066E 000.1008E 01
0.2480E 030.7109E 01	0.1033E 010.1008E 01
0.2490E 030.6739E 01	0.1363E 010.1008E 01
0.2500E 030.6367E 01	0.1697E 010.1008E 01
0.2510E 030.5993E 01	0.2034E 010.1007E 01
0.2520E 030.5617E 01	0.2374E 010.1007E 01
0.2530E 030.5240E 01	0.2717E 010.1007E 01
0.2540E 030.4862E 01	0.3062E 010.1007E 01
0.2550E 030.4482E 01	0.3409E 010.1006E 01
0.2560E 030.4101E 01	0.3759E 010.1006E 01
0.2570E 030.3718E 01	0.4109E 010.1006E 01
0.2580E 030.3335E 01	0.4461E 010.1005E 01

0.2590E 030.2950E 01	0.4814E 010.1005E 01
0.2600E 030.2565E 01	0.5168E 010.1005E 01
0.2610E 030.2178E 01	0.5521E 010.1005E 01
0.2620E 030.1791E 01	0.5875E 010.1004E 01
0.2630E 030.1404E 01	0.6228E 010.1004E 01
0.2640E 030.1015E 01	0.6581E 010.1004E 01
0.2650E 030.6267E 00	0.6932E 010.1004E 01
0.2660E 030.2376E 00	0.7282E 010.1003E 01
0.2670E 03-.1516E 00	0.7631E 010.1003E 01
0.2680E 03-.5413E 00	0.7977E 010.1003E 01
0.2690E 03-.9309E 00	0.8321E 010.1002E 01
0.2700E 03-.1321E 01	0.8662E 010.1002E 01
0.2710E 03-.1710E 01	0.9001E 010.1002E 01
0.2720E 03-.2099E 01	0.9336E 010.1002E 01
0.2730E 03-.2488E 01	0.9667E 010.1001E 01
0.2740E 03-.2877E 01	0.9994E 010.1001E 01
0.2750E 03-.3265E 01	0.1032E 020.1001E 01
0.2760E 03-.3653E 01	0.1063E 020.1000E 01
0.2770E 03-.4040E 01	0.1095E 020.1000E 01
0.2780E 03-.4426E 01	0.1126E 020.9998E 00
0.2790E 03-.4811E 01	0.1156E 020.9995E 00
0.2800E 03-.5195E 01	0.1185E 020.9992E 00
0.2810E 03-.5579E 01	0.1214E 020.9989E 00
0.2820E 03-.5961E 01	0.1243E 020.9987E 00
0.2830E 03-.6341E 01	0.1270E 020.9984E 00
0.2840E 03-.6721E 01	0.1297E 020.9981E 00
0.2850E 03-.7099E 01	0.1323E 020.9978E 00
0.2860E 03-.7475E 01	0.1348E 020.9975E 00
0.2870E 03-.7849E 01	0.1373E 020.9972E 00
0.2880E 03-.8222E 01	0.1396E 020.9969E 00
0.2890E 03-.8593E 01	0.1419E 020.9967E 00
0.2900E 03-.8962E 01	0.1441E 020.9964E 00
0.2910E 03-.9329E 01	0.1461E 020.9961E 00

0.2920E 03-.9693E 01	0.1481E 020.9958E 00
0.2930E 03-.1006E 02	0.1500E 020.9956E 00
0.2940E 03-.1042E 02	0.1518E 020.9953E 00
0.2950E 03-.1077E 02	0.1534E 020.9950E 00
0.2960E 03-.1113E 02	0.1550E 020.9947E 00
0.2970E 03-.1148E 02	0.1564E 020.9945E 00
0.2980E 03-.1183E 02	0.1577E 020.9942E 00
0.2990E 03-.1217E 02	0.1589E 020.9939E 00
0.3000E 03-.1252E 02	0.1600E 020.9936E 00
0.3010E 03-.1286E 02	0.1610E 020.9934E 00
0.3020E 03-.1319E 02	0.1618E 020.9931E 00
0.3030E 03-.1352E 02	0.1625E 020.9929E 00
0.3040E 03-.1385E 02	0.1631E 020.9926E 00
0.3050E 03-.1418E 02	0.1636E 020.9923E 00
0.3060E 03-.1450E 02	0.1639E 020.9921E 00
0.3070E 03-.1482E 02	0.1641E 020.9918E 00
0.3080E 03-.1513E 02	0.1641E 020.9916E 00
0.3090E 03-.1544E 02	0.1640E 020.9913E 00
0.3100E 03-.1575E 02	0.1638E 020.9911E 00
0.3110E 03-.1605E 02	0.1634E 020.9908E 00
0.3120E 03-.1635E 02	0.1629E 020.9906E 00
0.3130E 03-.1664E 02	0.1622E 020.9904E 00
0.3140E 03-.1692E 02	0.1614E 020.9901E 00
0.3150E 03-.1721E 02	0.1605E 020.9899E 00
0.3160E 03-.1748E 02	0.1594E 020.9897E 00
0.3170E 03-.1776E 02	0.1582E 020.9894E 00
0.3180E 03-.1802E 02	0.1568E 020.9892E 00
0.3190E 03-.1829E 02	0.1553E 020.9890E 00
0.3200E 03-.1854E 02	0.1536E 020.9888E 00
0.3210E 03-.1879E 02	0.1518E 020.9886E 00
0.3220E 03-.1904E 02	0.1499E 020.9883E 00
0.3230E 03-.1928E 02	0.1478E 020.9881E 00
0.3240E 03-.1951E 02	0.1456E 020.9879E 00

0.3250E 03-.1974E 02	0.1432E 020.9877E 00
0.3260E 03-.1996E 02	0.1407E 020.9875E 00
0.3270E 03-.2018E 02	0.1381E 020.9873E 00
0.3280E 03-.2039E 02	0.1353E 020.9871E 00
0.3290E 03-.2059E 02	0.1324E 020.9870E 00
0.3300E 03-.2079E 02	0.1294E 020.9868E 00
0.3310E 03-.2098E 02	0.1263E 020.9866E 00
0.3320E 03-.2117E 02	0.1230E 020.9864E 00
0.3330E 03-.2134E 02	0.1196E 020.9862E 00
0.3340E 03-.2151E 02	0.1161E 020.9861E 00
0.3350E 03-.2168E 02	0.1125E 020.9859E 00
0.3360E 03-.2184E 02	0.1088E 020.9857E 00
0.3370E 03-.2199E 02	0.1049E 020.9856E 00
0.3380E 03-.2213E 02	0.1010E 020.9854E 00
0.3390E 03-.2226E 02	0.9698E 010.9853E 00
0.3400E 03-.2239E 02	0.9285E 010.9851E 00
0.3410E 03-.2251E 02	0.8863E 010.9850E 00
0.3420E 03-.2263E 02	0.8433E 010.9849E 00
0.3430E 03-.2273E 02	0.7995E 010.9847E 00
0.3440E 03-.2283E 02	0.7549E 010.9846E 00
0.3450E 03-.2292E 02	0.7096E 010.9845E 00
0.3460E 03-.2301E 02	0.6636E 010.9844E 00
0.3470E 03-.2309E 02	0.6169E 010.9843E 00
0.3480E 03-.2315E 02	0.5698E 010.9842E 00
0.3490E 03-.2321E 02	0.5221E 010.9841E 00
0.3500E 03-.2327E 02	0.4739E 010.9840E 00
0.3510E 03-.2331E 02	0.4254E 010.9839E 00
0.3520E 03-.2335E 02	0.3764E 010.9838E 00
0.3530E 03-.2338E 02	0.3272E 010.9837E 00
0.3540E 03-.2340E 02	0.2777E 010.9836E 00
0.3550E 03-.2342E 02	0.2281E 010.9835E 00
0.3560E 03-.2342E 02	0.1783E 010.9835E 00
0.3570E 03-.2342E 02	0.1284E 010.9834E 00

```
0.3580E 03-.2341E 02          0.7853E 000.9834E 00
0.3590E 03-.2340E 02          0.2867E 000.9833E 00
0.3600E 03-.2337E 02          -.2110E 000.9833E 00
0.3610E 03-.2334E 02          -.7071E 000.9832E 00
0.3620E 03-.2330E 02          -.1201E 010.9832E 00
0.3630E 03-.2325E 02          -.1693E 010.9832E 00
0.3640E 03-.2319E 02          -.2181E 010.9831E 00
0.3650E 03-.2313E 02          -.2666E 010.9831E 00
C
C DATA USED FOR SUBROUTINE GAUSS.
C
      6
            +0.000000000000000     +2.000000000000000
            -0.577350269189626     +1.000000000000000
            -0.577350269189626     +1.000000000000000
            -0.774596669241483     +0.555555555555555
            +0.000000000000000     +0.888888888888889
            +0.774596669241483     +0.555555555555555
            -0.861136311594053     +0.347854845137454
            -0.339981043584856     +0.652145154862546
            +0.339981043584856     +0.652145154862546
            +0.861136311594053     +0.347854845137454
            -0.906179845938664     +0.236926885056189
            -0.538469310105683     +0.478628670499366
            +0.000000000000000     +0.568888888888889
            +0.538469310105683     +0.478628670499366
            +0.906179845938664     +0.236926885056189
            -0.932469514203152     +0.171324492379170
            -0.661209386466265     +0.360761573048139
            -0.238619186083197     +0.467913934572691
            +0.238619186083197     +0.467913934572691
            +0.661209386466265     +0.360761573048139
            +0.932469514203152     +0.171324492379170
```

```
C
C TWO EXAMPLES OF RUN CONTROL CARDS :
C
 EDMONTON             EDM.IND.AFT.+53 35 +113 30 -00 50 105 001 365 01 01/01 31/12 7
 EDMONTON             EDM.IND.AFT.+53 35 +113 30 -00 50 105 001 365 01 01/01 31/12 6
```

APPENDIX F

WEATHER DATA, ANALYSIS PROGRAM AND TABLES

F1. Sources of Weather Data

When field tractability was used as the criterion for cutting forage, the series of X's and .'s representing 'good' and 'bad' days respectively were taken from tables given by Rutledge (107) for the Edmonton area. When other sets of criteria were used to obtain 'good' and 'bad' day probabilities, daily maximum and minimum temperatures, daily precipitation, daily average wind speed and daily bright sunshine hours were copied from D.O.T. monthly summaries of weather at the Edmonton Industrial Airport. Day lengths and daily solar radiation at the top of the atmsophere were obtained from the program listed in Appendix E. Data for June through September, 1950 to 1969, were chosen so as to include all likely starting and finishing dates for the two cuts prevalent in the Edmonton region.

F2. The Weather Analysis Program

Because the weather pattern during the forage growing season deviates a varying amount from the long-term norm, calendar dates only approximate the maturity date of the crop. Russell (106) used June 20 to July 15 and August 15 to September 18 for the first and second cuts of hay in the Red Deer area. Different starting dates and period durations were tested over the 20 years of weather history to see what changes in cumulative probability curves might result. In terms of field tractability, Rutledge (107) noted that good and bad days exhibited persistence.

Allowance was made in the data analysis for this contingency.

The criteria used by Borgman and Brooker as referenced by Jeffers (67) were included as a comparison for the arbitrary set of criteria, and not because the resulting probability curves could in any way be applicable to Alberta haying conditions. The arbitrary set of criteria were nothing but an experienced guesstimate, reasonable but subjective. Mean daily dew-point temperature was calculated using either a regression equation developed by Baier and Robertson (3) or, as in subroutine CRITB, a psychrometric equation developed by Brooker (17).

F3. Weather Probability Tables

Tables F1 through F7 summarize the more pertinent output of the analysis program. The changes in probability corresponding to a change in harvest date or a period extension are quite noticeable.

```
*            C PROGRAM FOR WEATHER PROBABILITIES USING HISTORICAL WEATHER DATA -
*            C     AS RECORDED IN EDMONTON, ALBERTA (1921 THROUGH 1969).
*            C
*   ISN   1        REAL*8 NAME,NAMEA,NAMEB,NAMEC,NAMED,NAMEE,NAMEF,NAMEX
*   ISN   2        INTEGER*4 DYOFYR
*   ISN   3        EXTERNAL HIST
*   ISN   4        DIMENSICN MAXT(20,122),MINT(20,122),PRECIP(20,122),AVWSPD(20,122),
*                 1BSUNSH(20,122),QO(122),DAYHRS(122),DAYS(45,122),INC(2),WORD(20),
*                 2NAME(6,3),NAMEX(3),NAMEA(4),NAMEB(4),NAMEC(4),NAMED(4),NAMEE(4),
*                 3NAMEF(4),DYOFYR(12)
*   ISN   5        DIMENSICN UBO(3),SUBSET(122),STATS(5),FREQ(120),PCT(120)
*            C
*            C DATA INITIALIZATICN :
*            C
*   ISN   6        DATA NAME(1,1),NAME(1,2),NAME(1,3)/'JUNE 15 ','TO JULY ','15
*                 1'/
*   ISN   7        DATA NAME(2,1),NAME(2,2),NAME(2,3)/'JUNE 20 ','TO JULY ','15
*                 1'/
*   ISN   8        DATA NAME(3,1),NAME(3,2),NAME(3,3)/'AUGUST 1',' TO SEPT','EMBER 10
*                 1'/
*   ISN   9        DATA NAME(4,1),NAME(4,2),NAME(4,3)/'AUGUST 1','5 TO SEP','TEMBER18
*                 1'/
*   ISN  10        DATA NAME(5,1),NAME(5,2),NAME(5,3)/'JUNE 15 ','TO SEPTE','MBER 15
*                 1'/
*   ISN  11        DATA NAME(6,1),NAME(6,2),NAME(6,3)/'JUNE 20 ','TO SEPTE','MBER 20
*                 1'/
*   ISN  12        DATA NAMEA/'BORGMAN ','AND BROO','KER''S CR','ITERIA  '/
*   ISN  13        DATA NAMEB/'''RAIN'' 0','R ''NO RA','IN'' CRIT','ERIA    '/
*   ISN  14        DATA NAMEC/'ARBITRAR','Y SET OF',' DRYING ','CRITERIA'/
*   ISN  15        DATA NAMED/'RUTLEDGE',' TRACTAB','ILITY CR','ITERIA 1'/
*   ISN  16        DATA NAMEE/'RUTLEDGE',' TRACTAB','ILITY CR','ITERIA 2'/
*   ISN  17        DATA NAMEF/'POTENTIA','L EVAPOT','RANSPIRA','TION.   '/
*   ISN  18        DATA DYOFYR/166,196,171,196,213,253,227,261,166,258,171,263/
```

```
*          ISN  19       DATA GOOD,BAD/'X','.'/
*                C
*                C    READ IN DATA :
*          ISN  20        INC=5
*          ISN  21        IOP=6
*                C
*                C
*                C       READ IN DATA TAKEN FROM P.L. RUTLEDGE'S THESIS.
*                C       FIELD TRACTABILITY IS THE PRIME CRITERION FOR THE WORK--NON-WORK
*                C       MATRIX FOR THE EDMONTON AREA.  THIS CRITERION USED FOR FORAGE
*                C       CUTTING IN THE EDMONTON AREA.
*                C
*                C       THE YEARS OF INTEREST ARE FROM 1921 TO 1965 INCLUSIVE.
*                C
*                C       A.  FIRST FOR HEAVY TO MEDIUM SOILS.
*                C
*          ISN  22       READ (INC,5) (WORD(I),I=1,20)
*          ISN  23       WRITE(IOP,6) (WORD(I),I=1,20)
*          ISN  24     5 FORMAT (20A4)
*          ISN  25     6 FORMAT (    3X,'P.L.RUTLEDGE''S FIELD TRACTABILITY CRITERION USED.
*                       1'/,20A4/)
*          ISN  26       DO 30 I=1,45
*          ISN  27       READ (INC,7)  (DAYS(I,J),J=1,30)
*          ISN  28       READ (INC,8)  (DAYS(I,J),J=31,61)
*          ISN  29       READ (INC,8)  (DAYS(I,J),J=62,92)
*          ISN  30       READ (INC,7)  (DAYS(I,J),J=93,122)
*          ISN  31    30 CONTINUE
*          ISN  32     7 FORMAT (17X,30A1)
*          ISN  33     8 FORMAT (17X,31A1)
*          ISN  34       WRITE (IOP,9)
*          ISN  35     9 FORMAT (3X,'DAY',10X,'FOR THE YEARS 1921 THROUGH 1965'/)
*          ISN  36       DO 31 J=1,30
*          ISN  37    31 WRITE (IOP,10) J,(DAYS(I,J),I=1,45)
```

```
*          ISN  38   10 FORMAT (1X,'JUNE ',I2,1X,45A1)
*          ISN  39      DO 32 J=31,61
*          ISN  40      K=J-30
*          ISN  41   32 WRITE (IOP,11) K,(DAYS(I,J),I=1,45)
*          ISN  42   11 FORMAT (1X,'JULY ',I2,1X,45A1)
*          ISN  43      DO 33 J=62,92
*          ISN  44      K=J-61
*          ISN  45   33 WRITE (IOP,12) K,(DAYS(I,J),I=1,45)
*          ISN  46   12 FORMAT (1X,'AUG. ',I2,1X,45A1)
*          ISN  47      DO 34 J=93,122
*          ISN  48      K=J-92
*          ISN  49   34 WRITE (IOP,13) K,(DAYS(I,J),I=1,45)
*          ISN  50   13 FORMAT (1X,'SEPT.',I2,1X,45A1)
*              C
*              C DATA MANIPULATIONS :
*              C
*              C      DATES USED BY RUSSELL FOR THE TWO CUTS OF HAY IN THE EDMONTON AREA
*              C      ARE (2) AND (4).
*              C      CLASSIFY AND TABULATE DAYS AS 'WORK' OR 'NON-WORK' DAYS, 'GOOD'
*              C      OR 'BAD' DAYS.  FIND DISTRIBUTION OF DAYS FOR THE FOLLOWING SIX
*              C      PERIODS:
*              C
*              C      (1) JUNE 15 TO JULY 15
*              C      (2) JUNE 20 TO JULY 15
*              C      (3) AUGUST 1 TO SEPTEMBER 10
*              C      (4) AUGUST 15 TO SEPTEMBER 18
*              C      (5) JUNE 15 TO SEPTEMBER 15
*              C      (6) JUNE 20 TO SEPTEMBER 20
*              C
*          ISN  51      JMAX=45
*          ISN  52      DO 40 J=2,12,2
*          ISN  53      I=J-1
*          ISN  54      K=J/2
```

```
*
*         ISN  55        INC(1)=DYOFYR(I)
*         ISN  56        IND(2)=DYOFYR(J)
*         ISN  57        DO  39 NN=1,3
*         ISN  58     39 NAMEX(NN)=NAME(K,NN)
*         ISN  59     40 CALL OUTPUT (IOP,DAYS,INC,NAMEX,NAMED,JMAX,1,1,HIST)
*                  C
*                  C     B.  NEXT FOR SANDY SOILS.
*                  C
*         ISN  60     46 READ (INC,5) (WORD(I),I=1,20)
*         ISN  61        WRITE(IOP,6) (WORD(I),I=1,20)
*         ISN  62        DO 50 I=1,45
*         ISN  63        READ (INC,7)  (DAYS(I,J),J=1,30)
*         ISN  64        READ (INC,8)  (DAYS(I,J),J=31,61)
*         ISN  65        READ (INC,8)  (DAYS(I,J),J=62,92)
*         ISN  66     50 READ (INC,7)  (DAYS(I,J),J=93,122)
*         ISN  67        WRITE (IOP,9)
*         ISN  68        DO 51 J=1,30
*         ISN  69     51 WRITE (IOP,10) J,(DAYS(I,J),I=1,45)
*         ISN  70        DO 52 J=31,61
*         ISN  71        K=J-30
*         ISN  72     52 WRITE (IOP,11) K,(DAYS(I,J),I=1,45)
*         ISN  73        DO 53 J=62,92
*         ISN  74        K=J-61
*         ISN  75     53 WRITE (IOP,12) K,(DAYS(I,J),I=1,45)
*         ISN  76        DO 54 J=93,122
*         ISN  77        K=J-92
*         ISN  78     54 WRITE (IOP,13) K,(DAYS(I,J),I=1,45)
*                  C
*                  C DATA MANIPULATICNS :
*                  C
*                  C     DATES USED BY RUSSELL FOR THE TWO CUTS OF HAY IN THE EDMONTON AREA
*                  C     ARE (2) AND (4).
*                  C     CLASSIFY AND TABULATE DAYS AS 'WORK' OR 'NON-WORK' DAYS, 'GOOD'
```

```
*                 C      OR 'BAD' DAYS.  FIND DISTRIBUTION OF DAYS FOR THE FOLLOWING SIX
*                 C      PERIODS:
*                 C
*                 C      (1) JUNE 15 TO JULY 15
*                 C      (2) JUNE 20 TO JULY 15
*                 C      (3) AUGUST 1 TO SEPTEMBER 10
*                 C      (4) AUGUST 15 TO SEPTEMBER 18
*                 C      (5) JUNE 15 TC SEPTEMBER 15
*                 C      (6) JUNE 20 TO SEPTEMBER 20
*                 C
*       ISN  79          JMAX=45
*       ISN  80          DO  60 J=2,12,2
*       ISN  81          I=J-1
*       ISN  82          K=J/2
*       ISN  83          INO(1)=DYOFYR(I)
*       ISN  84          INO(2)=DYOFYR(J)
*       ISN  85          DC  59 NN=1,3
*       ISN  86       59 NAMEX(NN)=NAME(K,NN)
*       ISN  87       60 CALL OUTPUT (IOP,DAYS,INO,NAMEX,NAMEE,JMAX,1,1,HIST)
*                 C STORAGE AREAS ERASED :
*                 C
*       ISN  88          DC 70 I=1,122
*       ISN  89          QO(I)=0.000000
*       ISN  90       70 DAYHRS(I)=0.000000
*       ISN  91          DO 75 I=1,20
*       ISN  92          DC 75 J=1,122
*       ISN  93          MAXT(I,J)=0
*       ISN  94          MINT(I,J)=0
*       ISN  95          PRECIP(I,J)=0.000000
*       ISN  96          AVWSPD(I,J)=0.000000
*       ISN  97       75 BSUNSH(I,J)=0.000000
*                 C
*                 C
```

```
*              C PROGRAM FOR WEATHER PROBABILITIES USING HISTORICAL WEATHER DATA -
*              C AS RECORDED IN EDMONTON,ALBERTA(1950 THROUGH 1969).
*              C DATA READ IN :
*              C
*    ISN  98        INC=5
*    ISN  99        IOP=6
*              C
*              C    DAYLENGTH LIST.
*    ISN 100        READ(INC,1) (DAYHRS(I),I=1,122)
*    ISN 101      1 FORMAT (26X,F6.2)
*              C    SOLAR ENERGY AT THE TOP OF THE ATMOSPHERE.
*    ISN 102        READ(INC,2) (GO(I),I=1,122)
*    ISN 103      2 FORMAT (70X,F6.1)
*              C    MAX. AND MIN. TEMPERATURES , TOTAL PRECIPITATION, AVERAGE WIND
*              C    SPEED, AND DURATION OF BRIGHT SUNSHINE.
*    ISN 104        DO  76 I=1,20
*    ISN 105        DO  76 J=1,121,2
*    ISN 106        JP1=J+1
*    ISN 107        READ (INC,3) IYR,MAXT1,MINT1,IPREC1,IWSPD1,IBSUN1,MAXT2,MINT2,IPRE
*                  1C2,IWSPD2,IBSUN2
*    ISN 108      3 FORMAT (9X,I2,7X,5I3,21X,5I3)
*    ISN 109        MAXT(I,J  )=MAXT1
*    ISN 110        MAXT(I,JP1)=MAXT2
*    ISN 111        MINT(I,J  )=MINT1
*    ISN 112        MINT(I,JP1)=MINT2
*    ISN 113        PRECIP(I,J)=DFLOAT(IPREC1)/100.
*    ISN 114        PRECIP(I,JP1)=DFLOAT(IPREC2)/100.
*    ISN 115        AVWSPD(I,JP1)=DFLOAT(IWSPD2)/10.
*    ISN 116        AVWSPD(I,J)=DFLOAT(IWSPD1)/10.
*    ISN 117        BSUNSH(I,J)=DFLOAT(IBSUN1)/10.
*    ISN 118     76 BSUNSH(I,JP1)=DFLOAT(IBSUN2)/10.
*              C
*              C DATA MANIPULATIONS :
```

```
*              C
*              C     CLASSIFY AND TABULATE DAYS AS 'RAIN' OR 'NON-RAIN' DAYS.
*              C
*     ISN 119        CALL RAIN(PRECIP,DAYS,1)
*              C
*              C FIND DISTRIBUTION OF DAYS FOR RAINY AND NON-RAINY PERIODS FOR THE
*              C FOLLOWING SIX PERIODS:
*              C     (1) JUNE 15 TO JULY 15
*              C     (2) JUNE 20 TO JULY 15
*              C     (3) AUGUST 1 TO SEPTEMBER 10
*              C     (4) AUGUST 15 TO SEPTEMBER 18
*              C     (5) JUNE 15 TO SEPTEMBER 15
*              C     (6) JUNE 20 TO SEPTEMBER 20
*              C
*     ISN 120        JMAX=20
*     ISN 121        DO  80 J=2,12,2
*     ISN 122        I=J-1
*     ISN 123        K=J/2
*     ISN 124        INO(1)=DYOFYR(I)
*     ISN 125        INO(2)=DYOFYR(J)
*     ISN 126        DO  79 NN=1,3
*     ISN 127     79 NAMEX(NN)=NAME(K,NN)
*     ISN 128     80 CALL OUTPUT(IOP,DAYS,INO,NAMEX,NAMEB,JMAX,1,1,HIST)
*              C
*              C TABULATE FREQUENCIES AND PERCENT FREQUENCIES OVER CLASS INTERVALS OF
*              C RAINFALL (IN./DAY) FOR THE FOLLOWING SIX PERIODS:
*              C     (1) JUNE 15 TO JULY 15
*              C     (2) JUNE 20 TO JULY 15
*              C     (3) AUGUST 1 TO SEPTEMBER 10
*              C     (4) AUGUST 15 TO SEPTEMBER 18
*              C     (5) JUNE 15 TO SEPTEMBER 15
*              C     (6) JUNE 20 TO SEPTEMBER 20
*              C
```

```
*
*             C       LOWER LIMIT (IN./DAY)
*     ISN 129         UBO(1)=0.000000
*             C       NUMBER OF INTERVALS
*     ISN 130         UBO(2)=92.
*             C       UPPER LIMIT (IN./DAY)
*     ISN 131         UBO(3)=4.500000
*     ISN 132         DO  90 J=2,12,2
*     ISN 133         I=J-1
*     ISN 134         K=J/2
*     ISN 135         DO  85 II=1,122
*     ISN 136      85 SUBSET(II)=0.000000
*     ISN 137         IA=DYOFYR(I)-151
*     ISN 138         IB=DYOFYR(J)-151
*     ISN 139         DO  86 II=IA,IB
*     ISN 140      86 SUBSET(II)=1.000000
*     ISN 141         DO  89 NN=1,3
*     ISN 142      89 NAMEX(NN)=NAME(K,NN)
*             C       CONSIDER ONLY NON-ZERO VALUES.
*     ISN 143         OBS=1.0
*     ISN 144         CALL TABL(PRECIP,SUBSET,1,20,UBO,FREQ,PCT,STATS,20,122,OBS)
*     ISN 145      90 CALL TABOUT(IOP,UBO,FREQ,PCT,STATS,NAMEC,NAMEX,OBS,1,1,HIST)
*             C
*             C DATA MANIPULATIONS :
*             C
*             C
*             C BORGMAN AND BROOKER'S (MISSOURI) CRITERIA FOR HAYING 'WORK' AND
*             C 'NON-WORK' DAYS.
*             C       (1) AT LEAST 70% OF THE TOTAL DAYLIGHT HOURS ARE BRIGHT SUNSHINE
*             C       (2) PRECIPITATION IS LESS THAN 0.1 INCH FOR THE DAY
*             C       (3) PRECIPITATION IS LESS THAN 1.0 INCH FOR THE PREVIOUS DAY
*             C
*     ISN 146         CALL CRITA(IOP,PRECIP,BSUNSH,DAYHRS,DAYS,1)
*             C
```

```
*              C OBTAIN  DISTRIBUTIONS FOR THE FOLLOWING SIX PERIODS :
*              C THE DAYS USED BY RUSSELL (EDMONTON) FOR THE TWO CUTS OF HAY NORMAL TO
*              C THE EDMONTON AREA ARE (2) AND (4).
*              C     (1) JUNE 15 TO JULY 15
*              C     (2) JUNE 20 TO JULY 15
*              C     (3) AUGUST 1 TO SEPTEMBER 15
*              C     (4) AUGUST 15 TO SEPTEMBER 18
*              C     (5) JUNE 15 TO SEPTEMBER 15
*              C     (6) JUNE 20 TO SEPTEMBER 20
*              C
*      ISN 147       JMAX=20
*      ISN 148       DO 110 J=2,12,2
*      ISN 149       I=J-1
*      ISN 150       K=J/2
*      ISN 151       INO(1)=DYOFYR(I)
*      ISN 152       INO(2)=DYOFYR(J)
*      ISN 153       DO 109 NN=1,3
*      ISN 154   109 NAMEX(NN)=NAME(K,NN)
*      ISN 155   110 CALL OUTPUT(IOP,DAYS,INO,NAMEX,NAMEA,JMAX,1,1,HIST)
*              C
*              C ARBITRARY SET OF CRITERIA FOR HAYING 'WORK' AND 'NON-WORK' DAYS.
*              C SET NO. 1 :
*              C     (1) AT LEAST 75% OF THE TOTAL DAYLIGHT HOURS ARE BRIGHT SUNSHINE
*              C     (2) PRECIPITATION IS LESS THAN 0.05 INCH FOR THE DAY
*              C     (3) PRECIPITATION IS LESS THAN 0.50 INCH FOR THE PREVIOUS DAY
*              C SET NO. 2 :
*              C     (1) PRECIPITATION IS LESS THAN OR EQUAL TO 0.01 INCH FOR THE DAY
*              C     (2) PRECIPITATION IS LESS THAN 0.1 INCH FOR THE PREVIOUS DAY
*              C     (3) AVERAGE WIND SPEED AT THE 6 FOOT LEVEL IS GREATER THAN 10 MPH
*              C     (4) DAILY MEAN DEW POINT TEMPERATURE IS IN EXCESS OF 10 DEGREES
*              C         FARENHEIT BELOW THE DAILY MEAN TEMPEPATURE.
*              C IF THE DAY UNDER INSPECTION DOES NOT SATISFY THE FIRST SET OF CRITERIA
*              C IT IS TESTED BY THE SECOND SET.  A DAY PASSING EITHER ONE OF THE TWO
```

```
*                C SETS OF CRITERIA IS CLASSED AS A GOOD DAY.
*                C
*      ISN 156         CALL CRITC(IOP,MAXT,MINT,PRECIP,BSUNSH,AVWSPD,DAYHRS,DAYS,1)
*                C
*                C OBTAIN  DISTRIBUTIONS FOR THE FOLLOWING SIX PERIODS :
*                C     (1) JUNE 15 TO JULY 15
*                C     (2) JUNE 20 TO JULY 15
*                C     (3) AUGUST 1 TO SEPTEMBER 15
*                C     (4) AUGUST 15 TO SEPTEMBER 18
*                C     (5) JUNE 15 TO SEPTEMBER 15
*                C     (6) JUNE 20 TO SEPTEMBER 20
*                C
*      ISN 157         JMAX=20
*      ISN 158         DO 120 J=2,12,2
*      ISN 159         I=J-1
*      ISN 160         K=J/2
*      ISN 161         INO(1)=DYOFYR(I)
*      ISN 162         INO(2)=DYOFYR(J)
*      ISN 163         DO 119 NN=1,3
*      ISN 164     119 NAMEX(NN)=NAME(K,NN)
*      ISN 165     120 CALL OUTPUT(IOP,DAYS,INO,NAMEX,NAMEC,JMAX,1,1,HIST)
*                C
*                C DATA MANIPULATIONS :
*                C
*                C OBTAIN DAILY LATENT EVAPORATION AND POTENTIAL EVAPOTRANSPIRATION DATA
*                C FOR THE YEARS 1950 THROUGH 1969 FROM JUNE 1 TO SEPTEMBER 30 INCLUSIVE
*                C USING BAIER AND ROBERTSON'S (OTTAWA) EQUATIONS.
*                C
*      ISN 166         CALL CRITB(IOP,MAXT,MINT,PRECIP,AVWSPD,BSUNSH,QO,DAYHRS,DAYS,1)
*                C
*                C TABULATE FREQUENCIES AND PERCENT FREQUENCIES OVER CLASS INTERVALS OF
*                C POTENTIAL EVAPO-TRANSPIRATION (IN./DAY) FOR THE FOLLOWING SIX
*                C PERIODS :
```

```
*                C
*                C       (1) JUNE 15 TO JULY 15
*                C       (2) JUNE 20 TO JULY 15
*                C       (3) AUGUST 1 TO SEPTEMBER 15
*                C       (4) AUGUST 15 TO SEPTEMBER 18
*                C       (5) JUNE 15 TC SEPTEMBER 15
*                C       (6) JUNE 20 TC SEPTEMBER 20
*                C       LOWER LIMIT (IN./DAY)
*         ISN 167        UBO(1)=0.000000
*                C       NUMBER OF INTERVALS
*         ISN 168        UBO(2)=42.
*                C       UPPER LIMIT (IN./DAY)
*         ISN 169        UBO(3)=0.400000
*         ISN 170        DO 150 J=2,12,2
*         ISN 171        I=J-1
*         ISN 172        K=J/2
*         ISN 173        DO 140 II=1,122
*         ISN 174    140 SUBSET(II)=0.000000
*         ISN 175        IA=DYOFYR(I)-151
*         ISN 176        IB=DYOFYR(J)-151
*         ISN 177        DO 142 II=IA,IB
*         ISN 178    142 SUBSET(II)=1.000000
*         ISN 179        DO 149  NN=1,3
*         ISN 180    149 NAMEX(NN)=NAME(K,NN)
*                C       CONSIDER ONLY NON-ZERO VALUES.
*         ISN 181        OBS=1.
*         ISN 182        CALL TABL(DAYS,SUBSET,1,20,UBO,FREQ,PCT,STATS,20,122,OBS)
*         ISN 183    150 CALL TAROUT(ICP,UBO,FREQ,PCT,STATS,NAMEF,NAMEX,OBS,1,1,HIST)
*         ISN 184    200 CONTINUE
*         ISN 185        STOP
*         ISN 186        END
*         ISN   1        SUBROUTINE RAIN(PRECIP,DAYS,N)
*                C       SUBROUTINE USING 'RAIN' OR 'NO RAIN' CRITERIA TO ESTABLISH DAYS
```

```
*         C AS 'BAD' OR 'GOOD' RESPECTIVELY.
*  ISN  2        REAL NRAINF
*  ISN  3        DIMENSICN PRECIP(20,122),DAYS(20,122)
*  ISN  4        DATA NRAINF,RAINF,BLANK/'X','.',' '/
*  ISN  5        ICP=6
*         C      INITIALIZE MATRIX.
*  ISN  6        DO 10 I=1,20
*  ISN  7        DO 10 J=1,122
*  ISN  8     10 DAYS(I,J)=BLANK
*         C      DETERMINE WHETHER OR NOT EACH DAY IS A NON-RAIN DAY.
*  ISN  9        DO 25 I=1,20
*  ISN 10        DO 25 J=1,122
*  ISN 11        TEMP=PRECIP(I,J)
*  ISN 12        IF(TEMP) 15,15,20
*  ISN 13     15 DAYS(I,J)=NRAINF
*  ISN 14        GC TO 25
*  ISN 15     20 DAYS(I,J)=RAINF
*  ISN 16     25 CONTINUE
*         C      IF N IS NON-ZERO, A MATRIX PRINT-OUT IS REQUESTED.
*  ISN 17        IF (N) 30,30,40
*  ISN 18     30 GC TC 90
*         C      OUTPUT MATRIX OF  X AND . COMBINATIONS.
*  ISN 19     40 WRITE (IOP,100) NRAINF,RAINF
*  ISN 20    100 FORMAT (22X,'RAINFALL DATA FOR EDMONTON'/3X,'NO RAIN INDICATED BY
*               1A ''',A1,''' ; RAIN INDICATED BY A ''',A1,'''',1X/)
*  ISN 21        WRITE (IOP,101)
*  ISN 22    101 FORMAT (   4X,'DAY ',' 50 51 52 53 54 55 56 57 58 59 60 61 62 63',
*               1' 64 65 66 67 68 69'/)
*  ISN 23        DO 50 J=1,30
*  ISN 24     50 WRITE (IOP,102) (J,(DAYS(I,J),I=1,20))
*  ISN 25    102 FORMAT (1X,'JUNE ',I2,20(2X,A1))
*  ISN 26        DO 55 J=31,61
*  ISN 27        K=J-30
```

```
*        ISN  28    55 WRITE (IOP,103) (K,(DAYS(I,J),I=1,20))
*        ISN  29   103 FORMAT (1X,'JULY ',I2,20(2X,A1))
*        ISN  30       DO 60 J=62,92
*        ISN  31       K=J-61
*        ISN  32    60 WRITE (IOP,104) (K,(DAYS(I,J),I=1,20))
*        ISN  33   104 FORMAT (1X,'AUG. ',I2,20(2X,A1))
*        ISN  34       DO 65 J=93,122
*        ISN  35       K=J-92
*        ISN  36    65 WRITE (IOP,105) (K,(DAYS(I,J),I=1,20))
*        ISN  37   105 FORMAT (1X,'SEPT.',I2,20(2X,A1))
*        ISN  38    90 CONTINUE
*        ISN  39       RETURN
*        ISN  40       END


*        ISN   1       SUBROUTINE CRITA(IOP,PRECIP,BSUNSH,DAYHRS,DAYS,N)
*               C      SUBROUTINE USING CRITERIA OF BORGMAN AND BROOKER'S FOR HAYING WORK
*               C      AND NON-WORK DAYS.
*        ISN   2       DIMENSION PRECIP(20,122),BSUNSH(20,122),DAYHRS(122),DAYS(20,122)
*        ISN   3       DATA GOOD,BAD,BLANK/'X','.',' '/
*               C
*               C PARAMETERS :
*               C
*               C      -IOP IS THE OUTPUT DATA SET REFERENCE NUMBER.
*               C     -PRECIP IS A REAL MATRIX OF DAILY OBSERVED PRECIPITATION IN INCHES.
*               C     -BSUNSH IS A REAL MATRIX OF DAILY OBSERVED BRIGHT SUNSHINE HOURS.
*               C     -DAYHRS IS A REAL VECTOR OF DAYLENGTHS IN HOURS -- A FUNCTION OF
*               C      THE DAY OF THE YEAR.
*               C     -DAYS IS A REAL OUTPUT MATRIX GIVING 'GOOD' AND 'BAD' DAYS
*               C      ACCORDING TO THE SET OF CRITERIA USED.
*               C     -N IS A VALUE SIGNIFYING A PRINT-OUT REQUEST BY A NON-ZERO INTEGER.
*               C
*               C      INITIALIZE MATRIX.
```

```
*                 C
*        ISN   4         DO 10 I=1,20
*        ISN   5         DO 10 J=1,122
*        ISN   6      10 DAYS(I,J)=BLANK
*                 C
*                 C      DETERMINE WHETHER OR NOT EACH DAY IS A WORK DAY.
*                 C      SINCE MAY 31 PRECIPITATION IS NOT GIVEN, WE DON'T KNOW WHAT KIND
*                 C      OF A DAY JUNE 1 WAS.
*                 C
*        ISN   7         DO 25 I=1,20
*        ISN   8         DO 25 J=2,122
*        ISN   9         K=J-1
*        ISN  10         RATIO=BSUNSH(I,J)/DAYHRS(J)
*        ISN  11         IF(PRECIP(I,J).GE.0.1) GO TO 90
*        ISN  12         IF(PRECIP(I,K).GE.1.0) GO TO 90
*        ISN  13         IF(RATIO.LE.0.7) GO TO 90
*        ISN  14         DAYS(I,J)=GOOD
*        ISN  15         GO TO 25
*        ISN  16      90 DAYS(I,J)=BAD
*        ISN  17      25 CONTINUE
*        ISN  18         IF (N) 30,30,40
*        ISN  19      30 GO TO 95
*                 C
*                 C      OUTPUT MATRIX OF  X AND . COMBINATIONS.
*                 C
*        ISN  20      40 WRITE (6,99)
*        ISN  21      99 FORMAT ('1')
*        ISN  22         WRITE (IOP,100) GOOD,BAD
*        ISN  23     100 FORMAT (21X,'HAYING DAYS DATA FOR EDMONTON'/20X,'BORGMAN AND BROOK
*                       1ER''S CRITERIA'/3X,'A GOOD DAY INDICATED BY A ''',A1,'''; A BAD DA
*                       2Y INDICATED BY A '''A1,'''',1X/)
*        ISN  24         WRITE (IOP,101)
*        ISN  25     101 FORMAT (   4X,'DAY ',' 50 51 52 53 54 55 56 57 58 59 60 61 62 63',
```

```
*                 1' 64 65 66 67 68 69'/)
*  ISN  26           DO 50 J=1,30
*  ISN  27        50 WRITE (IOP,102) (J,(DAYS(I,J),I=1,20))
*  ISN  28       102 FORMAT (1X,'JUNE ',I2,20(2X,A1))
*  ISN  29           DO 55 J=31,61
*  ISN  30           K=J-30
*  ISN  31        55 WRITE (IOP,103) (K,(DAYS(I,J),I=1,20))
*  ISN  32       103 FORMAT (1X,'JULY ',I2,20(2X,A1))
*  ISN  33           DO 60 J=62,92
*  ISN  34           K=J-61
*  ISN  35        60 WRITE (IOP,104) (K,(DAYS(I,J),I=1,20))
*  ISN  36       104 FORMAT (1X,'AUG. ',I2,20(2X,A1))
*  ISN  37           DO 65 J=93,122
*  ISN  38           K=J-92
*  ISN  39        65 WRITE (IOP,105) (K,(DAYS(I,J),I=1,20))
*  ISN  40       105 FORMAT (1X,'SEPT.',I2,20(2X,A1))
*  ISN  41        95 CONTINUE
*  ISN  42           RETURN
*  ISN  43           END


*  ISN   1           SUBROUTINE CRITB(IOP,MAXT,MINT,PRECIP,AVWSPD,BSUNSH,QO,DAYHRS,PE,N
*                 1)
*           C        SUBROUTINE USING BAIER AND ROBERTSON'S LATENT EVAPORATION
*           C        EQUATIONS.
*  ISN   2           REAL*8 MONTH
*  ISN   3           REAL LE
*  ISN   4           DIMENSION MAXT(20,122),MINT(20,122),PRECIP(20,122),AVWSPD(20,122),
*                 1BSUNSH(20,122),QO(122),DAYHRS(122),LE(20,122),IYR(10),PE(20,122),
*                 2MONTH(4)
*  ISN   5           DATA MONTH/'JUNE ','JULY ','AUG. ','SEPT.'/
*           C
*           C PARAMETERS :
```

```
*                 C
*                 C     -IOP IS THE OUTPUT DATA SET REFERENCE NUMBER.
*                 C     -MAXT AND MINT ARE INTEGER MATRICES OF DAILY OBSERVED MAXIMUM AND
*                 C      MINIMUM TEMPERATURES IN DEGREES FARENHEIT.
*                 C     -PRECIP IS A REAL MATRIX OF DAILY OBSERVED PRECIPITATION IN INCHES.
*                 C     -AVWSPD IS A REAL MATRIX OF DAILY OBSERVED AVERAGE WIND SPEED IN
*                 C      MILES PER HOUR AT HEIGHT HX FEET.
*                 C     -BSUNSH IS A REAL MATRIX OF DAILY OBSERVED BRIGHT SUNSHINE HOURS.
*                 C     -QO IS A REAL VECTOR OF TOTAL SOLAR ENERGY AT THE TOP OF THE
*                 C      ATMOSPHERE IN CAL./(CM.**2-DAY).
*                 C     -DAYHRS IS A REAL VECTOR OF TOTAL HOURS PER DAY , A FUNCTION OF
*                 C      DAY OF THE YEAR, LATITUDE , ETC.
*                 C     -LE IS A REAL MATRIX OF CALCULATED LATENT EVAPORATION IN IN./DAY.
*                 C     -PE IS A REAL MATRIX OF CALCULATED POTENTIAL EVAPOTRANSPIRATION IN
*                 C      CC./DAY .
*                 C     -N IS A VALUE SIGNIFYING A PRINT-OUT REQUEST BY A NON-ZERO
*                 C      INTEGER.
*                 C
*                 C CLEAR STORAGE AREAS NOT CLEARED IN THE MAINLINE:
*                 C
*        ISN   6         DO 59 I=1,20
*        ISN   7         DO 59 J=1,122
*        ISN   8         LE(I,J)=0.000000
*        ISN   9      59 PE(I,J)=0.000000
*                 C
*                 C SET CONSTANT FACTOR :
*                 C      FOR HX OF 57 AND H6 OF 6 FEET, THE WIND FACTOR IS 0.4431701 .
*                 C
*                 C      HEIGHT OF ANEMOMETER IN FEET.
*        ISN  10         HX=57.
*        ISN  11         H6=6.
*                 C      FACTOR FOR REDUCING WIND RUN TO A 6-FOOT LEVEL.
*        ISN  12         WFACTR=ALOG(H6)/ALOG(HX)
```

```
*                C
*                C DATA MANIPULATIONS :
*                C
*       ISN  13    60 DO 110 I=1,20
*       ISN  14       DO 109 J=1,122
*                C    DIFFERENCE BETWEEN DAILY MAX. AND MIN. TEMPERATURE (DEGREES
*                C    FARENHEIT).
*       ISN  15       RANGE=MAXT(I,J)-MINT(I,J)
*                C    TOTAL SKY AND SOLAR ENERGY ON A HORIZONTAL SURFACE IN CAL./(CM.**2
*                C    *DAY)
*       ISN  16       QS=QO(J)*(0.251+0.616*BSUNSH(I,J)/DAYHRS(J))
*                C    TOTAL DAILY WIND RUN, IN MILES, AT 6 FEET ABOVE THE GROUND.
*       ISN  17       WIND=AVWSPD(I,J)*WFACTR*24.
*                C    ESTIMATED MEAN DAILY DEW-POINT TEMPERATURE ( DEGREES FARENHEIT).
*       ISN  18       TD=-12.58+0.52*MINT(I,J)+0.92*MAXT(I,J)-0.005*MAXT(I,J)**2.
*                C    MEAN AIR TEMPERATURE ( DEGREES FARENHEIT).
*       ISN  19       AIRT=(MAXT(I,J)+MINT(I,J))/2.
*                C    FIND VAPOUR PRESSURE DEFICIT FROM SATURATION VAPOUR PRESSURE AT
*                C    MEAN AIR TEMPERATURE AND AT MEAN DAILY DEW-POINT TEMPERATURE.
*                C    CONVERT DEGREES FARENHEIT TO DEGREES RANKINE, AND USE BROOKER'S
*                C    EQUATIONS.
*       ISN  20       T1=AIRT+459.69
*       ISN  21       IF(AIRT.GE.32.) GO TO 100
*                C    FOR TEMPERATURES BELOW FREEZING.
*       ISN  22       EW= EXP(23.3924-(11286.+.6489)/T1-0.46057*ALOG(T1))
*       ISN  23       GO TO 101
*                C    FOR TEMPERATURES ABOVE FREEZING.
*       ISN  24   100 EW= EXP(54.6329-(12301.+.688)/T1-5.16923*ALOG(T1))
*       ISN  25   101 T2=TD+459.69
*       ISN  26       IF(TD.GE.32.) GO TO 105
*       ISN  27       ES= EXP(23.3924-(11286.+.6489)/T2-0.46057*ALOG(T2))
*       ISN  28       GO TO 106
*       ISN  29   105 ES= EXP(54.6329-(12301.+.688)/T2-5.16923*ALOG(T2))
```

```
           C      FIND THE DEFICIT IN PSI AND CONVERT TO MB.
ISN   30   106 VPDEF=(FW-ES)*68.9
           C      FIND ESTIMATED LATENT EVAPORATION IN CC/DAY.
ISN   31          TMAX=MAXT(I,J)
ISN   32          LE(I,J)=-53.39+0.337*TMAX+0.531*RANGE+0.0107*QO(J)+0.0512*QS+0.097
                 17*WIND+1.77*VPDEF
           C      SET ALL NEGATIVE VALUES TO ZERO.
ISN   33          IF(LE(I,J)) 107,108,108
ISN   34   107 LE(I,J)=0.000000
           C      CONVERT LE(CC/DAY) TO PE(IN/DAY).
ISN   35   108 PE(I,J)=LE(I,J)*0.0034
ISN   36   109 CONTINUE
ISN   37   110 CONTINUE
ISN   38          IF (N) 120,150,120
           C
           C OUTPUT ROUTINE :
           C
ISN   39   120 WRITE (6,99)
ISN   40    99 FORMAT ('1',1X)
ISN   41          WRITE (IOP,1)
ISN   42     1 FORMAT (1X,'LATENT EVAPORATION TABLE',' FOR EDMONTON CITY --','FOR
                 1 THE YEARS 1950 THROUGH 1969.'/)
ISN   43          WRITE (IOP,2)
ISN   44     2 FORMAT (3X,'DAY',31X,'YEAR')
ISN   45          DO 10 I=1,10
ISN   46    10 IYR(I)=49+I
ISN   47          WRITE (IOP,3) (IYR(I),I=1,10)
ISN   48     3 FORMAT (8X,10(2X,I2,3X)/)
ISN   49     4 FORMAT (1X,A5,I2,10(1X,F6.3))
ISN   50          DO 15 J=1,30
ISN   51    15 WRITE (IOP,4) MONTH(1),J,(LE(I,J),I=1,10)
ISN   52          DO 16 J=31,61
ISN   53          K=J-30
```

```
*          ISN  54    16 WRITE (IOP,4) MONTH(2),K,(LE(I,J),I=1,10)
*          ISN  55       DO 17 J=62,92
*          ISN  56       K=J-61
*          ISN  57    17 WRITE (IOP,4) MONTH(3),K,(LE(I,J),I=1,10)
*          ISN  58       DO 18 J=93,122
*          ISN  59       K=J-92
*          ISN  60    18 WRITE (IOP,4) MONTH(4),K,(LE(I,J),I=1,10)
*          ISN  61       WRITE (IOP,4)
*          ISN  62       DO 25 I=1,10
*          ISN  63    25 IYR(I)=59+I
*          ISN  64       WRITE (IOP,2)
*          ISN  65       WRITE (IOP,3) (IYR(I),I=1,10)
*          ISN  66       DO 35 J=1,30
*          ISN  67    35 WRITE (IOP,4) MONTH(1),J,(LE(I,J),I=11,20)
*          ISN  68       DO 36 J=31,61
*          ISN  69       K=J-30
*          ISN  70    36 WRITE (IOP,4) MONTH(2),K,(LE(I,J),I=11,20)
*          ISN  71       DO 37 J=62,92
*          ISN  72       K=J-61
*          ISN  73    37 WRITE (IOP,4) MONTH(3),K,(LE(I,J),I=11,20)
*          ISN  74       DO 38 J=93,122
*          ISN  75       K=J-92
*          ISN  76    38 WRITE (IOP,4) MONTH(4),K,(LE(I,J),I=11,20)
*          ISN  77       WRITE (6,99)
*          ISN  78       WRITE (IOP,5)
*          ISN  79     5 FORMAT (1X,'POTENTIAL EVAPOTRANSPIRATION TABLE ','FOR EDMONTON CIT
*                       1Y -- 1950 - 1969.'/)
*          ISN  80       WRITE (IOP,2)
*          ISN  81       DO 40 I=1,10
*          ISN  82    40 IYR(I)=49+I
*          ISN  83       WRITE (IOP,3) (IYR(I),I=1,10)
*          ISN  84     6 FORMAT (1X,A5,I2,10(1X,F6.4))
*          ISN  85       DO 45 J=1,30
```

```
*          ISN  86    45 WRITE (IOP,6) MONTH(1),J,(PE(I,J),I=1,10)
*          ISN  87       DO 46 J=31,61
*          ISN  88       K=J-30
*          ISN  89    46 WRITE (IOP,6) MONTH(2),K,(PE(I,J),I=1,10)
*          ISN  90       DO 47 J=62,92
*          ISN  91       K=J-61
*          ISN  92    47 WRITE (IOP,6) MONTH(3),K,(PE(I,J),I=1,10)
*          ISN  93       DO 48 J=93,122
*          ISN  94       K=J-92
*          ISN  95    48 WRITE (IOP,6) MONTH(4),K,(PE(I,J),I=1,10)
*          ISN  96       WRITE (IOP,6)
*          ISN  97       DO 49 I=1,10
*          ISN  98    49 IYR(I)=59+I
*          ISN  99       WRITE (IOP,2)
*          ISN 100       WRITE (IOP,3) (IYR(I),I=1,10)
*          ISN 101       DO 55 J=1,30
*          ISN 102    55 WRITE (IOP,6) MONTH(1),J,(PE(I,J),I=11,20)
*          ISN 103       DO 56 J=31,61
*          ISN 104       K=J-30
*          ISN 105    56 WRITE (IOP,6) MONTH(2),K,(PE(I,J),I=11,20)
*          ISN 106       DO 57 J=62,92
*          ISN 107       K=J-61
*          ISN 108    57 WRITE (IOP,6) MONTH(3),K,(PE(I,J),I=11,20)
*          ISN 109       DO 58 J=93,122
*          ISN 110       K=J-92
*          ISN 111    58 WRITE (IOP,6) MONTH(4),K,(PE(I,J),I=11,20)
*          ISN 112   150 RETURN
*          ISN 113       END

*          ISN   1       SUBROUTINE CRITC(IOP,MAXT,MINT,PRECIP,BSUNSH,AVWSPD,DAYHRS,DAYS,N)
*                  C SUBROUTINE USING OWN CRITERIA AS SET OUT IN THE MAINLINE PROGRAM FOR
*                  C DETERMINING HAYING WORK AND NON-WORK DAYS.
```

```
*            ISN   2        DIMENSION PRECIP(20,122),BSUNSH(20,122),DAYHRS(122),DAYS(20,122),A
*                          1VWSPD(20,122),MAXT(20,122),MINT(20,122)
*            ISN   3        DATA GOOD,BAD,BLANK/'X','.',' '/
*                    C
*                    C PARAMETERS :
*                    C
*                    C      -IOP IS THE OUTPUT DATA SET REFERENCE NUMBER.
*                    C     -MAXT AND MINT ARE INTEGER MATRICES OF DAILY OBSERVED MAXIMUM AND
*                    C      MINIMUM TEMPERATURES IN DEGREES FARENHEIT.
*                    C     -PRECIP IS A REAL MATRIX OF DAILY OBSERVED PRECIPITATION IN INCHES.
*                    C     -BSUNSH IS A REAL MATRIX OF DAILY OBSERVED BRIGHT SUNSHINE HOURS.
*                    C     -AVWSPD IS A REAL MATRIX OF DAILY OBSERVED AVERAGE WIND SPEEDS IN
*                    C      MILES PER HOUR AT HEIGHT HX FEET.
*                    C     -DAYHRS IS A REAL VECTOR OF DAYLENGTHS IN HOURS -- A FUNCTION OF
*                    C      THE DAY OF THE YEAR.
*                    C     -DAYS IS A REAL OUTPUT MATRIX GIVING 'GOOD' AND 'BAD' DAYS
*                    C      ACCORDING TO THE SET OF CRITERIA USED.
*                    C     -N IS A VALUE SIGNIFYING A PRINT-OUT REQUEST BY A NON-ZERO INTEGER.
*                    C
*                    C      INITIALIZE MATRIX.
*                    C
*            ISN   4        DO 80 I=1,20
*            ISN   5        DO 80 J=1,122
*            ISN   6     80 DAYS(I,J)=BLANK
*                    C
*                    C      DETERMINE WHETHER OR NOT EACH DAY IS A WORK DAY.
*                    C      SINCE MAY 31 PRECIPITATION IS NOT GIVEN, WE DON'T KNOW WHAT KIND
*                    C      OF A DAY JUNE 1 WAS.
*                    C
*            ISN   7        H6=6.
*            ISN   8        HX=57.
*            ISN   9        WFACTR=ALOG(H6)/ALOG(HX)
*                    C
```

```
*
*          ISN  10         DO 96 I=1,20
*          ISN  11         DO 96 J=2,122
*          ISN  12         K=J-1
*          ISN  13         RATIO=BSUNSH(I,J)/DAYHRS(J)
*          ISN  14         IF(PRECIP(I,J).GE.0.05.OR.PRECIP(I,K).GE.0.5.OR.RATIO.LE.0.75) GO
*                         1TO 90
*          ISN  15         DAYS(I,J)=GOOD
*          ISN  16         GO TO 96
*                    C AVERAGE WIND SPEED AT 6 FOOT LEVEL IN M.P.H.
*          ISN  17      90 WIND6=AVWSPD(I,J)*WFACTR
*                    C ESTIMATED MEAN DAILY DEW-POINT TEMPERATURE IN DEGREES FARENHEIT.
*          ISN  18         TD=-12.58+0.52*MINT(I,J)+0.92*MAXT(I,J)-0.005*MAXT(I,J)**2.
*                    C MEAN AIR TEMPERATURE IN DEGREES FARENHEIT.
*          ISN  19         TMEAN=(MAXT(I,J)+MINT(I,J))/2.
*          ISN  20         TDIFF=TMEAN-TD
*          ISN  21         IF(PRECIP(I,J).GT.0.01.OR.PRECIP(I,J).GE.0.1.OR.TDIFF.LE.10..OR.WI
*                         1ND6.LE.10.) GO TO 95
*          ISN  22         DAYS(I,J)=GOOD
*          ISN  23         GO TO 96
*          ISN  24      95 DAYS(I,J)=BAD
*          ISN  25      96 CONTINUE
*                    C
*          ISN  26         IF (N) 110,110,115
*          ISN  27     110 GO TO 200
*                    C
*                    C     OUTPUT MATRIX OF  X AND . COMBINATIONS.
*                    C
*          ISN  28     115 WRITE (6,99)
*          ISN  29      99 FORMAT ('1')
*          ISN  30         WRITE (IOP,100) GOOD,BAD
*          ISN  31     100 FORMAT (21X,'HAYING DAYS DATA FOR EDMONTON'/24X, 'ARBITRARY SET OF
*                         1 CRITERIA'/3X,'A GOOD DAY INDICATED BY A ''',A1,''': A BAD DAY IND
*                         2ICATED BY A ''',A1,'''',1X/)
```

```
ISN  32        WRITE (IOP,101)
ISN  33    101 FORMAT (    4X,'DAY ',' 50 51 52 53 54 55 56 57 58 59 60 61 62 63',
             1' 64 65 66 67 68 69'/)
ISN  34        DO 50 J=1,30
ISN  35     50 WRITE (IOP,102) (J,(DAYS(I,J),I=1,20))
ISN  36    102 FORMAT (1X,'JUNE ',I2,20(2X,A1))
ISN  37        DO 55 J=31,61
ISN  38        K=J-30
ISN  39     55 WRITE (IOP,103) (K,(DAYS(I,J),I=1,20))
ISN  40    103 FORMAT (1X,'JULY ',I2,20(2X,A1))
ISN  41        DO 60 J=62,92
ISN  42        K=J-61
ISN  43     60 WRITE (IOP,104) (K,(DAYS(I,J),I=1,20))
ISN  44    104 FORMAT (1X,'AUG. ',I2,20(2X,A1))
ISN  45        DO 65 J=93,122
ISN  46        K=J-92
ISN  47     65 WRITE (IOP,105) (K,(DAYS(I,J),I=1,20))
ISN  48    105 FORMAT (1X,'SEPT.',I2,20(2X,A1))
ISN  49    200 CONTINUE
ISN  50        RETURN
ISN  51        END


ISN   1        SUBROUTINE TABL(A,S,IA,IB,UBO,FREQ,PCT,STATS,NV,NO,SONT)
             C SUBROUTINE TABL TABULATES FOR A SELECTED VARIABLE OR VARIABLES IN AN
             C OBSERVATION MATRIX, THE FREQUENCIES AND PERCENT FREQUENCIES OVER CLASS
             C INTERVALS.
             C SOURCE: ADAPTED FROM SUBROUTINE TAB1 GIVEN IN THE IBM SCIENTIFIC
             C SUBROUTINE PACKAGE, H20-0205-3.
ISN   2        DIMENSION A(20,122),S(122),UBO(3),FREQ(120),PCT(120),STATS(5),
             1WBO(3)
             C
             C PARAMETERS:
```

```
*
*               C      -A IS AN OBSERVATION MATRIX NV BY NO.
*               C      -S IS AN INPUT VECTOR OF LENGTH NO GIVING THE SUBSET OF A.  ONLY
*               C       THOSE OBSERVATIONS WITH A CORRESPONDING NON-ZERO S(J) ARE
*               C       CONSIDERED.
*               C      -IA AND IB SET THE LOWER AND UPPER BOUNDS ON THE VARIABLES OR ROWS
*               C       TO BE CONSIDERED.
*               C      -UBO IS AN INPUT VECTOR OF LENGTH 3 GIVING LOWER LIMIT, NUMBER OF
*               C       INTERVALS AND UPPER LIMIT.  IF L.L. = U.L., PROGRAM USES THE
*               C       MINIMUM AND MAXIMUM VALUES OF THE VARIABLE(S).  NUMBER OF INTER-
*               C       VALS, UBO(2), MUST INCLUDE 2 CELLS FOR VALUES UNDER AND ABOVE
*               C       LIMITS.
*               C      -FREQ IS AN OUTPUT VECTOR OF FREQUENCIES, VECTOR LENGTH UBO(2).
*               C      -PCT IS AN OUTPUT VECTOR OF RELATIVE FREQUENCIES, VECTOR LENGTH
*               C       UBO(2).
*               C      -STATS IS AN OUTPUT VECTOR OF SUMMARY STATISTICS ( TOTAL, AVERAGE,
*               C       STANDARD DEVIATION, MINIMUM, MAXIMUM) OF VECTOR LENGTH 5.
*               C      -SCNT IS AN INPUT REAL VALUE INDICATING WITH A NON-ZERO VALUE THAT
*               C       THE ZERO VALUES ARE TO BE IGNORED IN CALCULATING FREQ AND PCT.
*               C       THE VALUE RETURNED TO THE MAINLINE IS THE NUMBER OF CELLS IN A
*               C       OBSERVED.
*               C
*               C       STORE BOUNDS VECTOR.
*               C
*     ISN   3           DO 5 I=1,3
*     ISN   4         5 WBO(I)=UBO(I)
*               C
*               C       CALCULATE THE MINUMUM AND MAXIMUM.
*               C
*     ISN   5           VMIN=1.0E75
*     ISN   6           VMAX=-1.0E75
*     ISN   7           DO 30 I=IA,IB
*     ISN   8           DO 30 J=1,NO
*     ISN   9           IF(S(J)) 10,30,10
```

```
*        ISN  10    10 IF(A(I,J)-VMIN) 15,20,20
*        ISN  11    15 VMIN=A(I,J)
*        ISN  12    20 IF(A(I,J)-VMAX) 30,30,25
*        ISN  13    25 VMAX=A(I,J)
*        ISN  14    30 CONTINUE
*        ISN  15       STATS(4)=VMIN
*        ISN  16       STATS(5)=VMAX
*              C
*              C       DETERMINE LIMITS.
*              C
*        ISN  17       IZERO=0
*        ISN  18       IF(SCNT) 31,34,31
*        ISN  19    31 IZERO=1
*        ISN  20    34 IF(UBO(1)-UBO(3)) 40,35,40
*        ISN  21    35 UBO(1)=VMIN
*        ISN  22       UBO(3)=VMAX
*        ISN  23    40 INN=UBO(2)
*              C
*              C       CLEAR OUTPUT AREAS.
*              C
*        ISN  24       DO 45 I=1,INN
*        ISN  25       FREQ(I)=0.0
*        ISN  26    45 PCT(I)=0.0
*        ISN  27       DO 50 I=1,3
*        ISN  28    50 STATS(I)=0.0
*              C
*              C       CALCULATE INTERVAL SIZE.
*              C
*        ISN  29       SINT=ABS(UBO(3)-UBO(1))/(UBO(2)-2.0)
*              C
*              C       TEST SUBSET VECTOR.
*              C
*        ISN  30       SCNT=0.0
```

```
*
*     ISN  31        DO 75 I=IA,IB
*     ISN  32        DO 75 J=1,NC
*     ISN  33        IF(S(J)) 55,75,55
*     ISN  34     55 IF(IZERO) 56,57,56
*     ISN  35     56 IF(A(I,J)) 57,75,57
*     ISN  36     57 SCNT=SCNT+1.0
*              C
*              C     DEVELOP TOTAL AND FREQUENCIES.
*              C
*     ISN  37        STATS(1)=STATS(1)+A(I,J)
*     ISN  38        STATS(3)=STATS(3)+A(I,J)*A(I,J)
*     ISN  39        TEMP=UBO(1)-SINT
*     ISN  40        INTX=INN-1
*     ISN  41        DO 60 II=1,INTX
*     ISN  42        TEMP=TEMP+SINT
*     ISN  43        IF(A(I,J)-TEMP) 70,60,60
*     ISN  44     60 CONTINUE
*     ISN  45        IF(A(I,J)-TEMP) 75,65,65
*     ISN  46     65 FREQ(INN)=FREQ(INN)+1.0
*     ISN  47        GO TO 75
*     ISN  48     70 FREQ(II)=FREQ(II)+1.0
*     ISN  49     75 CONTINUE
*              C
*              C     CALCULATE RELATIVE FREQUENCIES.
*     ISN  50        DO 80 I=1,INN
*     ISN  51     80 PCT(I)=FREQ(I)*100.0/SCNT
*              C
*              C     CALCULATE MEAN AND STANDARD DEVIATION.
*              C
*     ISN  52        IF(SCNT-1.0) 85,85,90
*     ISN  53     85 STATS(2)=0.0
*     ISN  54        STATS(3)=0.0
*     ISN  55        GO TO 95
```

```
*          ISN  56    90 STATS(2)=STATS(1)/SCNT
*          ISN  57       STATS(3)=SQRT(ABS((STATS(3)-STATS(1)*STATS(1)/SONT)/(SONT-1.0)))
*                  C
*                  C     REPLACE BCUNDS VECTOR.
*                  C
*          ISN  58    95 DO 100 I=1,3
*          ISN  59   100 UBO(I)=WBO(I)
*          ISN  60       RETURN
*          ISN  61       END

*          ISN   1       SUBROUTINE TABOUT(IOP,UBO,FREQ,PCT,STATS,LABEL,NAMEX,OBS,IFPLOT,IC
*                       1PLOT,HIST)
*                  C SUBROUTINE TABOUT PRINTS OUT THE VALUES CALCULATED IN SUBROUTINE TABL,
*                  C AND CALLS FOR THE PLOT OR PLOTS REQUESTED BY THE MAINLINE.
*          ISN   2       REAL*8 NAMEX,LABEL
*          ISN   3       EXTERNAL HIST
*          ISN   4       DIMENSION UBO(3),FREQ(120),PCT(120),NAMEX(3),STATS(5),CUMPCT(120),
*                       1LABFL(4)
*                  C
*                  C PARAMETERS:
*                  C
*                  C    -IOP IS THE OUTPUT DATA SET REFERENCE NUMBER.
*                  C    -UBO IS AN INPUT VECTOR OF LENGTH 3 GIVING LOWER LIMIT, NUMBER OF
*                  C     INTERVALS AND UPPER LIMIT.
*                  C    -FREQ IS AN  INPUT VECTOR OF FREQUENCIES, VECTOR LENGTH UBO(2).
*                  C    -PCT IS AN  INPUT VECTOR OF RELATIVE FREQUENCIES, VECTOR LENGTH
*                  C     UBO(2).
*                  C    -STATS IS AN  INPUT VECTOR OF SUMMARY STATISTICS ( TOTAL, AVERAGE,
*                  C     STANDARD DEVIATION, MINIMUM, MAXIMUM) OF VECTOR LENGTH 5.
*                  C    -LABEL IS A DOUBLE PRECISION REAL VECTOR GIVING A 32-CHARACTER
*                  C     EXPLANATION OF THE CRITERIA USED.  VECTOR LENGTH IS 4.
*                  C    -NAMEX IS A DOUBLE PRECISION REAL VECTOR GIVING A 24-CHARACTER
```

```
*                 C      LABEL TO THE SUMMARY.  VECTOR LENGTH IS 3.
*                 C     -OBS IS THE NUMBER OF OBSERVATIONS MADE.
*                 C     -IFPLOT INDICATES A FREQUENCY PLOT OR HISTOGRAM PRINT-OUT BY A
*                 C      NON-ZERO INTEGER.
*                 C     -ICPLOT INDICATES A CUMULATIVE FREQUENCY PLOT OR HISTOGRAM
*                 C      PRINT-OUT BY A NON-ZERO INTEGER.
*                 C
*                 C      ZERO STORAGE AREAS:
*                 C
*        ISN   5         DO 10 I=1,120
*        ISN   6      10 CUMPCT(I)=0.000000
*                 C
*                 C      OUTPUT STATISTICAL DATA:
*                 C
*        ISN   7         WRITE (6,98)
*        ISN   8         WRITE (IOP,99)  (NAMEX(I),I=1,3)
*        ISN   9         WRITE (IOP,100) (LABEL(I),I=1,4)
*        ISN  10         WRITE (IOP,101) STATS(1)
*        ISN  11         WRITE (IOP,102) OBS
*        ISN  12         WRITE (IOP,103) STATS(2)
*        ISN  13         WRITE (IOP,104) STATS(3)
*        ISN  14         WRITE (IOP,105) STATS(4)
*        ISN  15         WRITE (IOP,106) STATS(5)
*        ISN  16         WRITE (IOP,107) UBO(1)
*        ISN  17         WRITE (IOP,108) UBO(3)
*        ISN  18      98 FORMAT ('1')
*        ISN  19      99 FORMAT      (1X,'STATISTICAL OUTPUT - PERIOD ',3A8/)
*        ISN  20     100 FORMAT (8X,' NOTE: ',4A8/)
*        ISN  21     101 FORMAT (8X,'TOTAL OF OBSERVATIONS  =',2X,F10.4)
*        ISN  22     102 FORMAT (8X,'NUMBER OF OBSERVATIONS =',2X,F10.4)
*        ISN  23     103 FORMAT (8X,'AVERAGE VALUE          =',2X,F10.4)
*        ISN  24     104 FORMAT (8X,'STANDARD DEVIATION     =',2X,F10.4)
*        ISN  25     105 FORMAT (8X,'MINIMUM VALUE          =',2X,F10.4)
```

```
*
*     ISN  26   106 FORMAT (8X,'MAXIMUM VALUE              =',2X,F10.4)
*     ISN  27   107 FORMAT (8X,'LOWER LIMIT CONSIDERED =',2X,F10.4)
*     ISN  28   108 FORMAT (8X,'UPPER LIMIT CONSIDERED =',2X,F10.4)
*     ISN  29   109 FORMAT (8X,'SIZE OF CLASS INTERVAL =',2X,F10.4)
*             C         SIZE OF INTERVAL.
*     ISN  30           SINT=ABS(UBO(3)-UBO(1))/(UBO(2)-2.0)
*     ISN  31           WRITE (IOP,109) SINT
*             C
*             C         OUTPUT FREQUENCY AND RELATED DATA:
*             C
*     ISN  32           WRITE (IOP,200) (NAMEX(I),I=1,3)
*     ISN  33   200 FORMAT     (/1X,'FREQUENCY DATA - PERIOD ',3A8/)
*     ISN  34           WRITE (IOP,201)
*     ISN  35   201 FORMAT (4X,'INTERVAL',30X,'CUMULATIVE'/4X,'OR LEVEL',5X,'FREQUENCY
*                  1',5X,'PERCENT',6X,'PERCENT'/3X,4('----------',3X)/)
*     ISN  36           SUMFRQ=0.0
*     ISN  37           SUMPCT=0.0
*     ISN  38           DO 50 I=1,120
*     ISN  39           TEMP=SINT*FLOAT(I)
*     ISN  40           SUMFRQ=SUMFRQ+FREQ(I)
*     ISN  41           SUMPCT=SUMPCT+PCT(I)
*     ISN  42           CUMPCT(I)=SUMPCT
*             C         PRINT ONLY NON-ZERO FREQUENCIES UP TO THE UPPER LIMIT.
*     ISN  43           IF(TEMP-UBO(3)) 35,35,55
*     ISN  44    35 IF(FREQ(I)) 50,50,45
*     ISN  45    45 WRITE (IOP,202) TEMP,FREQ(I),PCT(I),CUMPCT(I)
*     ISN  46   202 FORMAT (3X,4(F10.4,3X))
*     ISN  47    50 CONTINUE
*     ISN  48    55 WRITE (IOP,203) SUMFRQ,SUMPCT
*     ISN  49   203 FORMAT(3X,4('----------',3X)//4X,'TOTAL',7X,2(F10.4,3X))
*             C
*             C         TEST FOR FREQUENCY PLOT.
*             C
```

```
*
*   ISN  50        IF(IFPLOT) 60,70,60
*   ISN  51     60 CALL HIST (STATS,FREQ,SINT,UBO,LABEL,NAMEX,0,30,0.)
*            C
*            C     TEST FOR CUMULATIVE PERCENT PLOT.
*            C
*   ISN  52     70 IF(ICPLOT) 80,90,80
*   ISN  53     80 CALL HIST (STATS,CUMPCT,SINT,UBO,LABEL,NAMEX,0,30,0.)
*   ISN  54     90 RETURN
*   ISN  55        END

*   ISN   1        SUBROUTINE OUTPUT(IOP,DAYS,INO,ANAME,BNAME,JMAX,IFPLOT,ICPLOT,HIST
*                 1)
*            C
*            C     FIND THE FREQUENCY DISTRIBUTIONS FOR 'GOOD' AND 'BAD' DAYS.
*            C
*   ISN   2        REAL*8 ANAME,ENAME,AA,BB
*   ISN   3        INTEGER*4 GFREQ,BFREQ,BSUM,GSUM,GGSUM,GBSUM,BBSUM,BGSUM
*   ISN   4        EXTERNAL HIST
*   ISN   5        DIMENSION DAYS(45,122),GFREQ(45),BFREQ(45),ISUM(2),INO(2),ANAME(3)
*                 1,ENAME(4),PLOT(120),P(4),ICUMG(45),ICUMB(45)
*   ISN   6        DIMENSION STATS(5),UBO(3),TEMP(120)
*   ISN   7        DATA GOOD,BAD,BLANK,EX,AA,BB/'X','.',' ','*',' GOOD ',' BAD  '/
*            C
*            C PARAMETERS :
*            C
*            C    -IOP IS THE OUTPUT DATA SET REFFRENCE NUMBER .
*            C    -DAYS IS A REAL MATRIX OF 'GOOD' AND 'BAD' DAYS AS DEFINED BY THE
*            C     WEATHER CRITERIA USED.
*            C    -INO IS AN INTEGER VECTOR GIVING THE FIRST AND LAST DAYS CONSIDERED
*            C     FOR EACH YEAR.
*            C    -ANAME IS A DOUBLE PRECISION REAL VECTOR GIVING A 24-CHARACTER
*            C     LABEL TO THE TABLES. VECTOP LENGTH IS 3.
```

```
*
*               C     -BNAME IS A DOUBLE PRECISION REAL VECTOR GIVING A 32-CHARACTER
*               C      EXPLANATION OF THE CRITERIA USED.  VECTOR LENGTH IS 4.
*               C     -JMAX IS AN INTEGER VALUE GIVING THE UPPER NUMBER OF DAYS IN ANY
*               C      ONE SEQUENCE TO BE INCLUDED IN THE TABULATIONS.
*               C     -IFPLOT IS AN INTEGER VALUE INDICATING A REQUEST FOR A FREQUENCY
*               C      PLOT.
*               C     -ICPLOT IS AN INTEGER VALUE INDICATING A REQUEST FOR A CUMULATIVE
*               C      FREQUENCY PLOT.
*               C
*               C       INITIALIZE MATRICES.
*         ISN   8      DO 89 I=1,120
*         ISN   9   89 TEMP(I)=0.000000
*         ISN  10      DO 90  J=1,JMAX
*         ISN  11      ICUMG(J)=0
*         ISN  12      ICUMB(J)=0
*         ISN  13      GFREQ(J)=0
*         ISN  14   90 BFREQ(J)=0
*               C
*               C      ZERO ALL COUNTERS.
*               C      NON-WORK DAY. COUNTER.
*         ISN  15      BSUM=0
*               C      WORK DAY. COUNTER.
*         ISN  16      GSUM=0
*               C      NON-WORK DAY FOLLOWING A WORK DAY. COUNTER.
*         ISN  17      GBSUM=0
*               C      WORK DAY FOLLOWING A WORK DAY. COUNTER.
*         ISN  18      GGSUM=0
*               C      WORK DAY FOLLOWING A NON-WORK DAY. COUNTER.
*         ISN  19      BGSUM=0
*               C      NON-WORK DAY FOLLOWING A NON-WORK DAY. COUNTER.
*         ISN  20      BBSUM=0
*               C      NUMBER OF WORK PERIODS.
*               C      NUMBER OF NON-WORK PERIODS.
```

```
*
*          ISN   21       DO   91 I=1,2
*          ISN   22    91 ISUM(I)=0
*                   C     DETERMINE DAYS OF INTEREST.
*          ISN   23       JA=INO(1)-151
*          ISN   24       JB=INO(2)-151
*                   C
*                   C     FIND FREQUENCIES.
*          ISN   25    92 DO   98 I=1,JMAX
*          ISN   26       K=0
*          ISN   27       DO   97 J=JA,JB
*          ISN   28       JJ=J-1
*          ISN   29       IF(DAYS(I,J).EQ.GOOD) GO TO  94
*                   C
*                   C     FOR A 'EAD' DAY.
*          ISN   30       BSUM=BSUM+1
*          ISN   31       IF(DAYS(I,JJ).EQ.BAD) GO TO  93
*                   C     THE PREVIOUS DAY WAS A 'GOOD' ONE.
*                   C     I.E. A BAD DAY FOLLOWS A GOOD DAY.
*          ISN   32       GBSUM=GBSUM+1
*          ISN   33       IF(J.EQ.JA) GO TO  93
*          ISN   34       GFREQ(K)=GFREQ(K)+1
*          ISN   35       K=0
*          ISN   36    93 BBSUM=BBSUM+1
*          ISN   37       K=K+1
*          ISN   38       IF(J.NE.JB) GO TO 97
*          ISN   39       BFREQ(K)=BFREQ(K)+1
*          ISN   40       GO TO 97
*                   C
*                   C     FOR A 'GOOD' DAY.
*          ISN   41    94 GSUM=GSUM+1
*          ISN   42       IF(DAYS(I,JJ).EQ.GOOD) GO TO 95
*                   C     THE PREVIOUS DAY WAS A 'BAD' ONE.
*          ISN   43       BGSUM=BGSUM+1
```

```
*        ISN  44         IF(J.EQ.JA) GO TO 96
*        ISN  45         BFREQ(K)=BFREQ(K)+1
*        ISN  46         K=0
*                 C      I.E. A GOOD DAY FOLLOWS A GOOD DAY.
*        ISN  47      95 CGSUM=GGSUM+1
*        ISN  48      96 K=K+1
*        ISN  49         IF(J.NE.JB) GO TO 97
*        ISN  50         GFREQ(K)=GFREQ(K)+1
*        ISN  51      97 CONTINUE
*        ISN  52      98 CONTINUE
*        ISN  53         SUM   =DFLOAT(GSUM)+DFLOAT(BSUM)
*        ISN  54         P(1)=DFLOAT(GBSUM)/(DFLOAT(GBSUM)+DFLOAT(GGSUM))
*        ISN  55         P(2)=DFLOAT(GGSUM)/(DFLOAT(GBSUM)+DFLOAT(GGSUM))
*        ISN  56         P(3)=DFLOAT(BGSUM)/(DFLOAT(BGSUM)+DFLOAT(BBSUM))
*        ISN  57         P(4)=DFLOAT(BBSUM)/(DFLOAT(BGSUM)+DFLOAT(BBSUM))
*                 C      FIND THE TOTAL NUMBER OF GOOD AND BAD PERIODS, AND THE PROBABILITY
*                 C      OF A GOOD DAY.
*        ISN  58         DO  99 J=1,JMAX
*        ISN  59         ISUM(1)=ISUM(1)+GFREQ(J)
*        ISN  60         ISUM(2)=ISUM(2)+BFREQ(J)
*        ISN  61      99 CONTINUE
*        ISN  62         PROB   =DFLOAT(GSUM)/SUM
*        ISN  63         WRITE (6,7)
*        ISN  64       7 FORMAT ('1')
*        ISN  65         WRITE (IOP,8)((BNAME(I),I=1,4),(ANAME(J),J=1,3))
*        ISN  66       8 FORMAT (/1X,4A8,1X,3A8/)
*        ISN  67         WRITE (IOP,9)  PROB
*        ISN  68       9 FORMAT (1X,'THE PROBABILITY OF A GOOD DAY IN GIVEN PERIOD     =',F
*                       16.3)
*        ISN  69         WRITE (IOP,10) BB,AA,P(1)
*        ISN  70         WRITE (IOP,10) AA,AA,P(2)
*        ISN  71         WRITE (IOP,10) AA,BB,P(3)
*        ISN  72         WRITE (IOP,10) BB,BB,P(4)
```

```
*         ISN  73    10 FORMAT (1X,'THE PROBABILITY OF A',A6,'DAY FOLLOWING A',A6,'DAY=',F
*                      16.3)
*         ISN  74       WRITE (IOP,11) AA,ISUM(1)
*         ISN  75       WRITE (IOP,11) BB,ISUM(2)
*         ISN  76    11 FORMAT (1X,'THE NUMBER OF',A6,'PERIODS',24X,'=',I6)
*         ISN  77       WRITE (IOP,12) SUM
*         ISN  78    12 FORMAT (1X,'THE TOTAL NUMBER OF OBSERVED DAYS IN GIVEN PERIOD =',F
*                      17.1/)
*                 C
*                 C     CALCULATE CUMULATIVE PROBABILITY CURVES.
*         ISN  79       WRITE (IOP,14)
*         ISN  80    14 FORMAT(1X,'N GOOD',13X,'CUMULATIVE',2X,'N  BAD',13X,'CUMULATIVE'/2
*                      1(2X,'DAYS',2X,'FREQ.',1X,'PROB.',1X,'PROBABILITY')//)
*         ISN  81       I1=JMAX
*         ISN  82       I2=GFREQ(JMAX)
*         ISN  83       P2=DFLOAT(GFREQ(JMAX))/DFLOAT(ISUM(1))
*         ISN  84       P3=1.00000
*         ISN  85       ICUMG(JMAX)=100
*         ISN  86       I4=JMAX
*         ISN  87       I5=BFREQ(JMAX)
*         ISN  88       P5=DFLOAT(BFREQ(JMAX))/DFLOAT(ISUM(2))
*         ISN  89       P6=1.00000
*         ISN  90       ICUMB(JMAX)=100
*         ISN  91       WRITE (IOP,16) I1,I2,P2,P3,I4,I5,P5,P6
*         ISN  92    16 FORMAT (1X,2(2X,I2,3X,I4,2X,F5.3,4X,F5.3,3X))
*         ISN  93       JJ=JMAX-1
*         ISN  94       DO 124 J=1,JJ
*         ISN  95       K=JMAX-J
*         ISN  96       KP1=K+1
*         ISN  97       I1=I1-1
*         ISN  98       I2=GFREQ(K)
*         ISN  99       P2=DFLOAT(GFREQ(K))/DFLOAT(ISUM(1))
*         ISN 100       P3=P3-DFLOAT(GFREQ(KP1))/DFLOAT(ISUM(1))
```

```
*          ISN 101          ICUMG(K)=IFIX(P3*100.+0.5)
*          ISN 102          I4=I4-1
*          ISN 103          I5=BFREQ(K)
*          ISN 104          P5=DFLOAT(BFREQ(K))/DFLOAT(ISUM(2))
*          ISN 105          P6=P6-DFLCAT(BFREQ(KP1))/DFLOAT(ISUM(2))
*          ISN 106          ICUMB(K)=IFIX(P6*100.+0.5)
*          ISN 107      124 WRITE (IOP,16) I1,I2,P2,P3,I4,I5,P5,P6
*                   C
*          ISN 108          UBO(1)=0.0
*          ISN 109          UBO(3)=JMAX
*          ISN 110          UBO(2)=JMAX+2
*          ISN 111          SINT=1.0
*          ISN 112          IF(IFPLCT) 130,130,125
*                   C
*                   C       PLOT FREQUENCIES.
*          ISN 113      125 DC 126 I=1,5
*          ISN 114      126 STATS(I)=0.0
*          ISN 115          DO 128 I=1,JMAX
*          ISN 116          TEMP(I)=GFREG(I)
*          ISN 117          IF(GFREQ(I)) 128,128,127
*          ISN 118      127 STATS(5)=I
*          ISN 119      128 STATS(1)=STATS(1)+FLCAT(GFREQ(I)*I)
*          ISN 120          STATS(2)=STATS(1)/ISUM(1)
*          ISN 121          SUM=FLCAT(ISUM(1))
*          ISN 122          STATS(3)=SQRT(ABS((STATS(3)-STATS(1)*STATS(1)/SUM)/(SUM-1.0)))
*          ISN 123          CALL HIST(STATS,TEMP,SINT,UBO,BNAME,ANAME,0,JMAX,GOOD)
*          ISN 124      130 IF(ICPLCT) 135,135,131
*                   C
*                   C       PLCT CUMULATIVE PROBABILITY CURVES.
*          ISN 125      131 DO 132 I=1,JMAX
*          ISN 126      132 TEMP(I)=ICUMG(I)
*          ISN 127          CALL HIST(STATS,TEMP,SINT,UBO,BNAME,ANAME,0,JMAX,GOOD)
*          ISN 128      135 IF(IFPLOT) 140,140,136
```

```
*           C
*           C        PLOT FREQUENCIES.
*   ISN 129   136 DO 137 I=1,5
*   ISN 130   137 STATS(I)=0.0
*   ISN 131       DO 139 I=1,JMAX
*   ISN 132       TEMP(I)=BFREQ(I)
*   ISN 133       IF(BFREQ(I)) 139,139,138
*   ISN 134   138 STATS(5)=I
*   ISN 135   139 STATS(1)=STATS(1)+FLOAT(BFREQ(I)*I)
*   ISN 136       STATS(2)=STATS(1)/ISUM(2)
*   ISN 137       SUM=FLOAT(ISUM(2))
*   ISN 138       STATS(3)=SQRT(ABS((STATS(3)-STATS(1)*STATS(1)/SUM)/(SUM-1.0)))
*   ISN 139       CALL HIST(STATS,TEMP,SINT,UBO,BNAME,ANAME,0,JMAX,BAD)
*   ISN 140   140 IF(ICPLOT) 150,150,141
*           C
*           C        PLOT CUMULATIVE PROBABILITY CURVES.
*   ISN 141   141 DO 142 I=1,JMAX
*   ISN 142   142 TEMP(I)=ICUMB(I)
*   ISN 143       CALL HIST(STATS,TEMP,SINT,UBO,BNAME,ANAME,0,JMAX,BAD)
*   ISN 144   150 CONTINUE
*   ISN 145       RETURN
*   ISN 146       END


*   ISN   1       SUBROUTINE HIST(STATS,FREQ,SINT,UBO,LABEL,NAMEX,IFMIN,ICMAX,CHAR)
*           C
*           C SUBROUTINE HIST PLOTS A HISTOGRAM OF VECTOR VALUES TO FIT A PAGE OF
*           C 60 LINES BY 130 SPACES.  NOTE: CALLING PROGRAM MUST INDICATE USE OF
*           C THIS SUBROUTINE BY AN EXTERNAL STATEMENT.
*           C
*   ISN   2       REAL*8 NAMEX,LABEL
*   ISN   3       DIMENSION STATS(5),FREQ(120),NAMEX(3),UBO(3),IFR(30),YFREQ(50),
*                1HISTGM(50,30),LABEL(4)
```

```
*        ISN   4       DATA STAR,BLANK/'*',' '/
*                C
*                C PARAMETERS:
*                C
*                C    -UBO IS AN INPUT VECTOR OF LENGTH 3 GIVING LOWER LIMIT, NUMBER OF
*                C     INTERVALS AND UPPER LIMIT.
*                C    -FREQ IS AN  INPUT VECTOR OF FREQUENCIES, VECTOR LENGTH UBO(2).
*                C    -PCT IS AN  INPUT VECTOR OF RELATIVE FREQUENCIES, VECTOR LENGTH
*                C     UBO(2).
*                C    -STATS IS AN  INPUT VECTOR OF SUMMARY STATISTICS ( TOTAL, AVERAGE,
*                C     STANDARD DEVIATION, MINIMUM, MAXIMUM) OF VECTOR LENGTH 5.
*                C    -LABEL IS A DOUBLE PRECISION REAL VECTOR GIVING A 32-CHARACTER
*                C     EXPLANATION OF THE CRITERIA USED.  VECTOR LENGTH IS 4.
*                C    -NAMEX IS A DOUBLE PRECISION REAL VECTOR GIVING A 24-CHARACTER
*                C     LABEL TO THE HISTOGRAM.  VECTOR LENGTH IS 3.
*                C    -SINT INDICATES THE SIZE OF CLASS INTERVAL.
*                C    -IFMIN IS AN INPUT INTEGER VALUE GIVING THE LOWEST FREQUENCY TO BE
*                C     PLOTTED, THUS INDICATING THE LOWEST POINT ON THE Y-AXIS TO BE
*                C     PLOTTED.
*                C    -ICMAX IS AN INPUT INTEGER VALUE GIVING THE MAXIMUM NUMBER OF CLASS
*                C     INTERVALS TO BE PLOTTED.
*                C    -CHAR IS A REAL VALUE ( A SINGLE CHARACTER ) TO BE USED IN THE
*                C     HISTOGRAM TO BE PLOTTED.  THE DEFAULT CHARACTER IS A '*' .
*                C
*                C     DETERMINE THE PLOT CHARACTER TO BE USED.
*                C
*        ISN   5       IF(CHAR.EQ.0.) GO TO 99
*        ISN   6       STAR=CHAR
*                C
*                C     FIND LOWEST FREQUENCY VALUE TO BE PLOTTED.
*                C
*        ISN   7    99 FMIN=0+IFMIN
*                C     FIND THE NUMBER OF CLASS INTERVALS BY CHECKING TO FIND THE LAST
```

```
*
*              C      NON-ZERO ENTRY IN THE VECTOR FREQ.
*        ISN   8      J=ICMAX+1
*        ISN   9      DO 1 I=1,ICMAX
*        ISN  10      J=J-1
*        ISN  11      IF(FREQ(J)) 1,1,2
*        ISN  12    1 CONTINUE
*        ISN  13    2 ISUM=J
*              C
*        ISN  14      IB=0
*        ISN  15    4 IA=IB+1
*              C      ONLY 30 INTERVALS PER PAGE.
*        ISN  16      IB=IA+29
*        ISN  17      IF(IB-ISUM) 6,5,5
*        ISN  18    5 IB=ISUM
*              C      NUMBER OF CLASS INTERVALS TO BE PLOTTED ON THIS PAGE.
*        ISN  19    6 NOINT=IB-IA+1
*              C
*              C      WRITE HEADINGS.
*              C
*        ISN  20      WRITE (6,100) (STATS(I),I=1,5)
*        ISN  21  100 FORMAT ('1',1X,'SUMMARY STATISTICS:'/1X,'TOTAL =',F10.4,2X,'AVERAG
*                    1E =',F10.4,2X,'STANDARD DEVIATION =',F10.4,2X,'MINIMUM =',F10.4,2X
*                    2,'MAXIMUM =',F10.4)
*        ISN  22      WRITE (6,101) LABEL(1),LABEL(2),LABEL(3),LABEL(4),NAMEX(1),NAMEX(2
*                    1),NAMEX(3)
*        ISN  23  101 FORMAT (60X,'HISTOGRAM'/29X,4A8,' FOR THE PERIOD ',3A8)
*        ISN  24      J=0
*        ISN  25      DO 10 I=IA,IB
*        ISN  26      J=J+1
*        ISN  27      IFR(J)=INT(FREQ(I)+0.5)
*        ISN  28   10 CONTINUE
*        ISN  29      WRITE (6,102) (IFR(I),I=1,NOINT)
*        ISN  30  102 FORMAT (1X,'FREQUENCY ',30I4)
```

```
*
*     ISN  31          WRITE (6,103)
*     ISN  32      103 FORMAT (1X,130('-'))
*             C        FIND MAXIMUM FREQUENCY OCCURRING ON THE PAGE TO BE PRINTED.
*     ISN  33          FMAX=0.0
*     ISN  34          DO 15 I=IA,IB
*     ISN  35          IF(FMAX-FREQ(I)) 14,15,15
*     ISN  36       14 FMAX=FREQ(I)
*     ISN  37       15 CONTINUE
*     ISN  38          ERROR=10.**(-3.)
*     ISN  39          IF(ABS(FMAX-ERROR)) 4,4,16
*             C
*             C        FIND NUMBER OF OCCURRENCES PER INTERVAL PLOTTED -- A MAX. OF
*             C        50 'OCCURRENCE INCREMENTS'.
*             C
*     ISN  40       16 FINT=INT((FMAX-FMIN+1.)/50.+0.5)
*             C
*             C        CALCULATE Y-AXIS VALUES.
*             C
*     ISN  41          DO 20 I=1,50
*     ISN  42       20 YFREQ(I)=FINT*FLOAT(I)
*             C
*             C        ZERO HISTOGRAM MATRIX.
*             C
*     ISN  43          DO 25 I=1,50
*     ISN  44          DO 25 J=1,30
*     ISN  45       25 HISTGM(I,J)=BLANK
*             C
*             C        FILL IN HISTOGRAM MATRIX WITH FREQUENCY LEVELS.
*             C
*     ISN  46          J=0
*     ISN  47          DO 35 I=IA,IB
*     ISN  48          J=J+1
*             C        (FIND LEVELS REACHED TO THE NEAREST INTERVAL.)
```

```
*      ISN  49        IF(FREQ(I)) 35,35,26
*      ISN  50     26 K=INT(FREQ(I)/FINT+0.5)
*      ISN  51        DO 30 L=1,K
*      ISN  52     30 HISTGM(L,J)=STAR
*      ISN  53     35 CONTINUE
*               C
*               C     PRINT MATRIX AND Y-AXIS VALUES.
*               C
*      ISN  54        I=51
*      ISN  55        DO 40 JJ=1,50
*      ISN  56        I=I-1
*      ISN  57     40 WRITE (6,104) YFREQ(I),(HISTGM(I,J),J=1,NOINT)
*      ISN  58    104 FORMAT (1X,E10.4,1X,30(2X,A1,1X))
*               C     PRINT X-AXIS OR BASE OF HISTOGRAM.
*      ISN  59        WRITE (6,103)
*      ISN  60        DO 44 I=1,30
*      ISN  61     44 IFR(I)=0
*      ISN  62        DO 45 I=IA,IB
*      ISN  63     45 IFR(I)=I
*      ISN  64        WRITE (6,105) (IFR(I),I=1,NOINT)
*      ISN  65    105 FORMAT (1X,'INTERVAL ',1X,30I4/1X,'CLASS')
*      ISN  66        WRITE (6,106) SINT
*      ISN  67    106 FORMAT (1X,'INTERVAL ','CLASS SIZE =',F10.4)
*      ISN  68        IF(IB-ISUM) 4,50,50
*      ISN  69     50 RETURN
*      ISN  70        END
```

TABLE F1. CUMULATIVE WEATHER PROBABILITIES RELATED TO FORAGE CUTTING ON MEDIUM TO HEAVY SOILS[a].

Cumulative Probabilities Given a Sequence Starting With a

Sequence Length (days)	Bad Day						Good Day					
	p = 0.318	p = 0.320	p = 0.306	p = 0.324	p = 0.314	p = 0.325	q = 0.682	q = 0.680	q = 0.694	q = 0.676	q = 0.686	q = 0.675
	June 15 to July 15	June 20 to July 15	August 1 to Sept. 10	August 15 to Sept. 18	June 15 to Sept. 15	June 20 to Sept. 20	June 15 to July 15	June 20 to July 15	August 1 to Sept. 10	August 15 to Sept. 18	June 15 to Sept. 15	June 20 to Sept. 20
1	0.365	0.396	0.392	0.417	0.389	0.398	0.177	0.163	0.175	0.151	0.161	0.154
2	0.600	0.631	0.578	0.564	0.584	0.591	0.359	0.372	0.327	0.252	0.331	0.339
3	0.741	0.758	0.721	0.679	0.710	0.704	0.479	0.512	0.457	0.365	0.448	0.459
4	0.853	0.852	0.848	0.782	0.825	0.814	0.589	0.634	0.556	0.484	0.537	0.547
5	0.924	0.926	0.897	0.821	0.892	0.878	0.641	0.698	0.619	0.541	0.599	0.613
6	0.959	0.960	0.922	0.859	0.937	0.914	0.714	0.756	0.682	0.604	0.655	0.667
7	0.976	0.973	0.971	0.917	0.966	0.944	0.786	0.808	0.717	0.660	0.709	0.709
8	0.988	0.993	0.980	0.936	0.977	0.964	0.812	0.843	0.776	0.704	0.756	0.762
9	0.994	1.000	0.980	0.962	0.983	0.972	0.870	0.890	0.303	0.723	0.795	0.794
10	0.994		0.985	0.962	0.987	0.979	0.896	0.913	0.843	0.792	0.833	0.829
11	1.000		0.985	0.968	0.989	0.985	0.917	0.936	0.874	0.843	0.872	0.867
12			0.990	0.974	0.992	0.985	0.953	0.959	0.901	0.868	0.907	0.899
13			0.990	0.974	0.994	0.987	0.969	0.977	0.924	0.893	0.926	0.920
14			0.995	0.974	0.994	0.989	0.974	0.977	0.942	0.912	0.936	0.931
15			1.000	0.981	0.996	0.991	0.979	0.983	0.946	0.918	0.946	0.945
16				0.987	0.996	0.991	0.984	0.983	0.955	0.925	0.957	0.952
17				0.987	0.998	0.994	0.984	0.988	0.964	0.925	0.963	0.958
18				0.987	0.998	0.996	0.990	0.988	0.978	0.943	0.971	0.966
19				0.994	1.000	0.998	0.995	0.994	0.978	0.943	0.979	0.973
20				1.000		0.998	0.995	1.000	0.982	0.962	0.983	0.981

TABLE F1. (continued)

Sequence Length (days)	Cumulative Probabilities Given a Sequence Starting With a Bad Day						Good Day					
	p = 0.318	p = 0.320	p = 0.306	p = 0.324	p = 0.314	p = 0.325	q = 0.682	q = 0.680	q = 0.694	q = 0.676	q = 0.686	q = 0.675
	June 15 to July 15	June 20 to July 15	August 1 to Sept. 10	August 15 to Sept. 18	June 15 to Sept. 15	June 20 to Sept. 20	June 15 to July 15	June 20 to July 15	August 1 to Sept. 10	August 15 to Sept. 18	June 15 to Sept. 15	June 20 to Sept. 20
21						0.998	0.995		0.982	0.962	0.983	0.981
22						1.000	0.995		0.982	0.975	0.988	0.985
23							0.995		0.987	0.987	0.994	0.992
24							0.995		0.987	0.987	0.994	0.994
25							1.000		0.987	0.987	0.996	0.994
26									0.991	1.000	0.996	0.994
27									0.996		0.996	0.994
28									0.996		0.996	0.996
34									0.996		0.998	0.998
38									0.996		1.000	1.000
40									1.000			

[a] Taken from Rutledge's (107) tables of observed good and bad days for the period 1921 through 1965 at Edmonton.

Note: Blank cells or missing days indicate that values for these cells or days are the same as the previous value entered in the table.

TABLE F2. CUMULATIVE WEATHER PROBABILITIES RELATED TO FORAGE CUTTING ON SANDY SOILS[a]

Sequence Length (days)	Cumulative Probabilities Given a Sequence Starting With a Bad Day				Good Day			
	$p = 0.233$	$p = 0.236$	$p = 0.212$	$p = 0.212$	$q = 0.767$	$q = 0.764$	$q = 0.788$	$q = 0.788$
	June 15 to July 15	June 20 to July 15	August 1 to Sept. 10	August 15 to Sept. 18	June 15 to July 15	June 20 to July 15	August 1 to Sept. 10	August 15 to Sept. 18
1	0.537	0.569	0.516	0.488	0.183	0.173	0.159	0.156
2	0.832	0.844	0.852	0.741	0.361	0.371	0.315	0.263
3	0.942	0.952	0.915	0.865	0.521	0.553	0.446	0.360
4	0.989	0.994	0.978	0.935	0.589	0.629	0.570	0.473
5	0.995	0.994	0.996	0.971	0.653	0.716	0.622	0.538
6	0.995	0.994	0.996	0.976	0.726	0.766	0.693	0.618
7	1.000	1.000	0.996	0.982	0.790	0.812	0.737	0.694
8			0.996	0.988	0.817	0.843	0.765	0.715
9			1.000	1.000	0.872	0.893	0.793	0.731
10					0.904	0.924	0.833	0.806
11					0.918	0.939	0.853	0.844
12					0.932	0.954	0.892	0.866
13					0.954	0.964	0.920	0.892
14					0.977	0.980	0.944	0.919
15					0.982	0.985	0.948	0.919
16					0.986	0.985	0.956	0.925
17					0.986	0.990	0.960	0.930
18					0.991	0.990	0.972	0.946
19					0.995	0.995	0.976	0.946
20					0.995	1.000	0.984	0.962
21					0.995		0.984	0.968
22					0.995		0.984	0.973

TABLE F2. (continued)

Sequence Length (days)	Cumulative Probabilities Given a Sequence Starting With a							
	Bad Day				Good Day			
	$p = 0.233$	$p = 0.236$	$p = 0.212$	$p = 0.212$	$q = 0.767$	$q = 0.764$	$q = 0.788$	$q = 0.788$
	June 15 to July 15	June 20 to July 15	August 1 to Sept. 10	August 15 to Sept. 18	June 15 to July 15	June 20 to July 15	August 1 to Sept. 10	August 15 to Sept. 18
23					0.995		0.988	0.984
24					0.995		0.988	0.984
25					1.000		0.988	0.989
26							0.992	1.000
27							0.996	
40							1.000	

[a] Taken from Rutledge's (107) tables of observed good and bad days for the period 1921 through 1965 at Edmonton.

Note: Blank cells or missing days indicate that values for those cells or days are the same as the previous value entered in the table.

TABLE F3. CUMULATIVE PROBABILITIES FOR RAINY AND NON-RAINY DAYS[a].

Sequence Length (days)	Cumulative Probabilities Given a Sequence Starting With a											
	Rainy Day						Non-Rainy Day					
	p = 0.352	p = 0.346	p = 0.328	p = 0.281	p = 0.352	p = 0.343	q = 0.648	q = 0.654	q = 0.672	q = 0.719	q = 0.648	q = 0.657
	June 15 to July 15	June 20 to July 15	August 1 to Sept. 10	August 15 to Sept. 18	June 15 to Sept. 15	June 20 to Sept. 20	June 15 to July 15	June 20 to July 15	August 1 to Sept. 10	August 15 to Sept. 18	June 15 to Sept. 20	June 20 to Sept. 20
1	0.685	0.683	0.579	0.636	0.536	0.539	0.392	0.400	0.309	0.287	0.309	0.300
2	0.884	0.875	0.796	0.831	0.766	0.771	0.667	0.654	0.537	0.484	0.521	0.507
3	0.945	0.950	0.901	0.898	0.895	0.897	0.758	0.769	0.667	0.590	0.663	0.660
4	0.993	0.992	0.967	0.975	0.966	0.968	0.837	0.854	0.759	0.689	0.763	0.762
5	1.000	1.000	0.987	0.983	0.989	0.989	0.902	0.900	0.815	0.738	0.822	0.819
6			1.000	1.000	0.997	1.000	0.948	0.946	0.864	0.795	0.858	0.864
7					0.997		0.961	0.969	0.901	0.844	0.908	0.904
8					0.997		0.974	0.969	0.932	0.877	0.936	0.929
9					0.997		0.980	0.977	0.938	0.918	0.947	0.946
10					0.997		0.987	0.985	0.944	0.926	0.961	0.958
11					1.000		0.987	0.985	0.969	0.951	0.983	0.977
12							0.993	0.992	0.981	0.975	0.992	0.989
13							0.993	0.992	0.994	0.992	0.994	0.994
14							0.993	0.992	0.994	0.992	0.994	0.997
15							1.000	1.000	0.994	0.992	0.994	0.997
16									1.000	1.000	0.997	1.000
18											1.000	

[a]Data analyzed for the years 1950 through 1969 for the Edmonton area.

Note: Blank cells indicate that values for those cells are the same as the previous value entered in the table.

TABLE F4. CUMULATIVE RAINFALL PROBABILITIES[a]

Upper Limit of Interval (in./day)	Cumulative Probabilities Given Non-Zero Rainfall					
	June 15 to July 15	June 20 to July 15	August 1 to Sept. 10	August 15 to Sept. 18	June 15 to Sept. 15	June 20 to Sept. 20
0.10	0.230	0.219	0.234	0.279	0.232	0.229
0.15	0.455	0.438	0.405	0.457	0.416	0.412
0.20	0.562	0.552	0.539	0.589	0.528	0.527
0.25	0.630	0.620	0.643	0.690	0.618	0.616
0.30	0.660	0.651	0.684	0.721	0.657	0.657
0.35	0.732	0.729	0.747	0.792	0.725	0.724
0.40	0.766	0.766	0.796	0.822	0.763	0.763
0.45	0.804	0.802	0.822	0.838	0.797	0.798
0.50	0.843	0.844	0.829	0.848	0.823	0.823
0.55	0.847	0.849	0.844	0.858	0.835	0.835
0.60	0.877	0.880	0.851	0.868	0.853	0.854
0.65	0.894	0.901	0.862	0.878	0.873	0.875
0.70	0.915	0.917	0.862	0.883	0.885	0.887
0.75	0.919	0.922	0.888	0.909	0.898	0.900
0.80	0.919	0.922	0.896	0.919	0.901	0.903
0.85	0.928	0.922	0.914	0.939	0.913	0.912
0.90	0.932	0.922	0.926	0.944	0.924	0.922
0.95	0.953	0.948	0.929	0.949	0.936	0.934
1.00[b]	0.957	0.953	0.933	0.949	0.939	0.937

[a]Data analyzed for the years 1950 through 1969 for the Edmonton area.

[b]Tabulated data arbitrarily cut off at the 1" level since the cumulative curve is almost complete at this point.

TABLE F5. CUMULATIVE HAYING-DAY PROBABILITIES USING BORGMAN AND BROOKER'S CRITERIA[a].

Sequence Length (days)	Cumulative Probabilities Given a Sequence Starting With a Bad Day						Cumulative Probabilities Given a Sequence Starting With a Good Day					
	p = 0.650	p = 0.644	p = 0.577	p = 0.607	p = 0.607	p = 0.609	q = 0.350	q = 0.356	q = 0.423	q = 0.393	q = 0.393	q = 0.391
	June 15 to July 15	June 20 to July 15	August 1 to Sept. 10	August 15 to Sept. 18	June 15 to Sept. 15	June 20 to Sept. 20	June 15 to July 15	June 20 to July 15	August 1 to Sept. 10	August 15 to Sept. 18	June 15 to Sept. 15	June 20 to Sept. 20
1	0.310	0.357	0.412	0.336	0.351	0.356	0.492	0.500	0.455	0.485	0.480	0.484
2	0.512	0.548	0.618	0.591	0.547	0.553	0.836	0.837	0.731	0.720	0.756	0.753
3	0.643	0.687	0.741	0.723	0.700	0.701	0.926	0.923	0.892	0.864	0.900	0.890
4	0.783	0.800	0.818	0.781	0.791	0.789	0.975	0.971	0.934	0.932	0.943	0.934
5	0.853	0.870	0.882	0.854	0.866	0.864	0.992	0.990	0.958	0.962	0.965	0.964
6	0.915	0.930	0.924	0.898	0.912	0.909	1.000	1.000	0.970	0.977	0.984	0.984
7	0.961	0.965	0.941	0.920	0.941	0.936			0.988	0.985	0.995	0.995
8	0.969	0.974	0.953	0.942	0.957	0.952			0.994	0.992	0.997	0.997
9	0.977	0.991	0.976	0.964	0.976	0.973			1.000	1.000	1.000	1.000
10	0.992	1.000	0.982	0.971	0.979	0.976						
11	0.992		0.994	0.978	0.987	0.987						
12	0.992		0.994	0.985	0.992	0.995						
13	0.992		0.994	0.985	0.992	0.995						
14	0.992		0.994	0.985	0.992	0.995						
15	0.992		0.994	0.985	0.992	0.995						
16	1.000		1.000	1.000	1.000	1.000						

[a]Data analyzed for the years 1950 through 1969 for the Edmonton area.

Note: Blank cells indicate that values for those cells are the same as the previous value entered in the table.

TABLE F6. CUMULATIVE HAYING–DAY PROBABILITIES USING THE ARBITRARY SET OF CRITERIA[a].

Sequence Length (days)	Cumulative Probabilities Given a Sequence Starting With a Bad Day						Cumulative Probabilities Given a Sequence Starting With a Good Day					
	p = 0.726	p = 0.721	p = 0.651	p = 0.681	p = 0.683	p = 0.685	q = 0.274	q = 0.279	q = 0.349	q = 0.319	q = 0.317	q = 0.315
	June 15 to July 15	June 20 to July 15	August 1 to Sept. 10	August 15 to Sept. 18	June 15 to Sept. 15	June 20 to Sept. 20	June 15 to July 15	June 20 to July 15	August 1 to Sept. 10	August 15 to Sept. 18	June 15 to Sept. 15	June 20 to Sept. 20
1	0.225	0.287	0.331	0.264	0.265	0.277	0.510	0.494	0.500	0.508	0.505	0.495
2	0.405	0.446	0.537	0.480	0.440	0.452	0.892	0.882	0.805	0.771	0.812	0.798
3	0.550	0.594	0.656	0.600	0.590	0.593	0.971	0.965	0.922	0.907	0.945	0.928
4	0.712	0.713	0.750	0.688	0.708	0.699	0.971	0.965	0.948	0.958	0.954	0.943
5	0.775	0.782	0.831	0.768	0.783	0.777	0.990	0.988	0.981	0.983	0.982	0.978
6	0.856	0.861	0.862	0.832	0.831	0.825	1.000	1.000	0.994	0.992	0.994	0.991
7	0.901	0.891	0.881	0.856	0.870	0.861			0.994	0.992	0.997	0.994
8	0.919	0.921	0.906	0.896	0.901	0.901			1.000	1.000	1.000	0.997
9	0.928	0.931	0.956	0.952	0.943	0.952						
10	0.955	0.960	0.981	0.968	0.964	0.970						
11	0.982	0.970	0.994	0.976	0.976	0.976						
12	0.982	0.980	0.994	0.976	0.976	0.979						
13	0.982	0.980	0.994	0.984	0.979	0.985						
14	0.982	0.990	0.994	0.984	0.982	0.991						
15	0.982	0.990	0.994	0.984	0.982	0.991						
16	1.000	0.990	1.000	0.992	0.997	0.997						
17		1.000		0.992		1.000						
19				1.000								

[a]Data analyzed for the years 1950 through 1969 for the Edmonton area. Maximum sequence length considered was 20 days.

Note: Blank cells or missing days indicate that values for these cells or days are the same as the previous value entered in the table.

TABLE F7. CUMULATIVE PROBABILITIES OF POTENTIAL EVAPOTRANSPIRATION[a]

Upper Level of Interval (in./day)	Cumulative Probabilities Given Non-Zero P.E.					
	June 15 to July 15	June 20 to July 15	August 1 to Sept. 10	August 15 to Sept. 18	June 15 to Sept. 15	June 20 to Sept. 20
0.02	0.005	0.004	0.043	0.058	0.024	0.025
0.03	0.021	0.015	0.078	0.109	0.048	0.050
0.04	0.040	0.033	0.108	0.158	0.075	0.080
0.05	0.066	0.054	0.183	0.212	0.109	0.117
0.06	0.092	0.079	0.154	0.256	0.139	0.151
0.07	0.127	0.115	0.234	0.324	0.180	0.196
0.08	0.153	0.138	0.288	0.397	0.222	0.242
0.09	0.197	0.183	0.341	0.471	0.269	0.291
0.10	0.229	0.213	0.396	0.529	0.312	0.335
0.11	0.268	0.252	0.480	0.621	0.374	0.397
0.12	0.315	0.298	0.549	0.696	0.429	0.452
0.13	0.368	0.350	0.618	0.764	0.492	0.514
0.14	0.424	0.410	0.689	0.824	0.557	0.580
0.15	0.490	0.481	0.753	0.873	0.625	0.646
0.16	0.560	0.552	0.828	0.922	0.696	0.715
0.17	0.644	0.637	0.874	0.945	0.765	0.781
0.18	0.755	0.748	0.916	0.957	0.837	0.847
0.19	0.806	0.806	0.940	0.975	0.880	0.889
0.20	0.871	0.867	0.967	0.989	0.923	0.928
0.21	0.916	0.915	0.985	0.992	0.955	0.960
0.22	0.956	0.956	0.995	0.998	0.976	0.978
0.23	0.976	0.979	0.999	1.000	0.987	0.989
0.24	0.990	0.988	1.000		0.996	0.996
0.25	0.994	0.992			0.997	0.997
0.26	0.997	0.996			0.999	0.999
0.27	0.998	0.998			1.000	0.999
0.28	1.000	1.000				1.000

[a]Data analyzed for the years 1950 through 1969 for the Edmonton area.

APPENDIX G

GPSS PROGRAM FOR ALTERNATIVE SYSTEMS

NOT USING FIELD CURING

The program contained in this appendix, listed in a form similar to that of the initial phase output, includes the symbolic block references as punched onto the computer cards. In the assembly phase, these references are converted to their numeric equivalents. Consequently, any blocks using actual numeric block references, such as the TRANSFER block in the PICK mode or the LOOP block, must be altered if blocks are added to or deleted from the program. Although most of the non-block entities may be inserted at any point in the program between the SIMULATE card and the TERMINATE block, they must be introduced before any block referring to them.

This program represents that portion of the macro-network including arrows labelled 'high-moisture silage' and 'dehydrated alfalfa'. See figures 5 and 6 for the network of possibilities considered -- neither exhaustive nor all-inclusive.

```
            G.P.S.S. PROGRAM - NO FIELD CURING PRIOR TO STORAGE            0
                HIGH MOISTURE SILAGE AND DEHYDRATED ALFALFA                0
                                                                           0
        REALLOCATE BLO,700,FSV,120,HSV,120,VAR,110,FUN,35,LOG,20,TAB,0     0
        REALLOCATE XAC,2000,FAC,0,STO,0,BVR,0,CHA,0,QUE,0,COM,60000        0
        SIMULATE                                                           1
1       GENERATE   ,,,5                                                    2
        UNLIST                                                             3
* LIST OF HALF-WORD SAVEVALUES :                                           4
* NO.             ITEM                                    UNIT             5
* ---             ----                                    ----             6
*  1     COST OF CHEAPEST PROTEIN SOURCE                  CENTS/T.         7
*  2     COST OF CHEAPEST ENERGY  SOURCE                  CENTS/BU.        8
*  3     BUSHEL EQUIVALENT OF ENERGY SOURCE               LB./BU.          9
*  4     D.C.P. OF PROTEIN SOURCE                         % X10           10
*  5     D.C.P. OF ENERGY  SOURCE                         % X10           11
*  6     D.E. OF PROTEIN SOURCE                           KCAL./LB.       12
*  7     D.E. OF ENERGY  SOURCE                           KCAL./LB.       13
*  8     D.P.   OF FORAGE AT PRE-BLOOM/EARLY BUD STAGE  %X10 D.M.BASIS    14
*  9     D.E.   OF FORAGE AT PRE-BLOOM/EARLY BUD STAGE  KCAL/LB           15
* 10     MOISTURE CONTENT(WET BASIS) OF MATERIAL IN POINT   %             16
* 11     HIGH MOISTURE SILAGE (3 '' THEOR. LENGTH OF CUT)  HPHR/TDM X10   17
* 12     WILTED GRASS  SILAGE (1/2-1/4''THEOR. L. OF CUT)  HPHR/TDM X10   18
* 13     HAYLAGE              (1/2-1/4''THEOR. L. OF CUT)  HPHR/TDM X10   19
* 14     SALVAGE VALUE                                    %               20
* 15     ACRES                                            ACRES           21
* 16     DRY MATTER YIELD FIRST CUT                       T.DM./AC.X10    22
* 17     DISTANCE FROM FIELD TO STORAGE                    MILES          23
* 18     DRY MATTER YIELD SECOND CUT                      T.DM./AC.X10    24
* 19     AVERAGE OPERATING HR. PER YEAR FOR TRACTORS.          HR.        25
* 20     COST OF LABOUR                                   CENTS/HR.       26
* 21     COST OF ELECTRICITY                          CENTS/KWH.X100      27
* 22     COST OF GASOLINE                               CENTS/GAL.X10     28
```

*	23	COST OF DIESEL	CENTS/GAL.X10
*	24	COST OF PROPANE	CENTS/GAL.X10
*	25	COST OF BALE TWINE	CENTS/10,000 FT.
*	26	INITIAL COST OF GASOLINE TRACTOR	$/PTO.HP.
*	27	INITIAL COST OF DIESEL TRACTOR	$/PTO.HP.
*	28	INITIAL COST OF PROPANE TRACTOR	$/PTO.HP.
*	29	PWR. REQMT. OF MATERIAL IN POINT	HP-HR/T.DM. X10
*	30	INTEREST RATE	%
*	31	INSURANCE RATE	% X10
*	32	MACHINERY HOUSING RATE	%
*	33	AMORT. RATE ON PULL-TYPE IMPLEMENTS,ETC.	% X10
*	34	AMORT. RATE ON POWERED UNITS,WAGONS,ETC.	% X10
*	35	AMORT. RATE ON DUG-OUTS;WOOD,GALVANIZED AND	
*		PORTABLE BUILDINGS	% X10
*	36	AMORT. RATE ON CONCRETE AREAS OR BUILDINGS;	
*		STEEL SILOS	% X10
*	37	SILO FILLINGS PER YEAR	NO. X10
*	38	REST ALLOWANCE ON MACHINE-CONTROLLED TASKS	% X10
*	39	REST ALLOWANCE ON MANUAL OR DEMANDING TASKS	% X10
*	40	CUSTOM CHARGE FOR A 35-40 H.P. TRACTOR	CENTS/HR.
*	41	CUSTOM CHARGE FOR A FARM TRUCK	CENTS/HR.
*	42	SPEED - RAKING	M.P.H. X10
*	43	SPEED - BALING	M.P.H. X10
*	44	SPEED - FORAGE HARVESTING	M.P.H. X10
*	46	EFFICIENCY - DEHYDRATOR	%
*	47	HAYLAGE M.C. (W.B.)	%
*	48	WILTED GRASS SILAGE M.C. (W.B.)	%
*	49	HIGH MOISTURE SILAGE M.C. (W.B.)	%
*	50	FIELD EFFICIENCY - MOWER	%
*	51	FIELD EFFICIENCY - WINDROWER	%
*	52	FIELD EFFICIENCY - RAKE	%
*	53	FIELD EFFICIENCY - BALER ALONE	%
*	54	FIELD EFFICIENCY - BALER + WAGON	.

*	55	FIELD EFFICIENCY - FORAGE HARVESTER	%	62
*	56	EFFICIENCY - WAGON WITH THROWN BALES	%	63
*	57	EFFICIENCY - ELECTRIC MOTOR	%	64
*	58	CAPACITY - FARM TRUCK PAYLOAD	T./LD. X2	65
*	59	CAPACITY - FARM WAGON PAYLOAD	T./LD. X2	66
*	60	CAPACITY - TOWER SILO UNLOADER	T./HR. X10	67
*	61	CAPACITY - LIGHT BALER	T./HR. X10	68
*	62	CAPACITY - HEAVY-DUTY BALER	T./HR. X10	69
*	63	CAPACITY - WAFERER	T./HR. X10	70
*	64	CAPACITY - FLIGHT & CHAIN CONVEYOR	LIN. F.P.M.	71
*	65	AVG. GAS. CONSUMPTION	GAL./PTO.HP.-HR.X1000	72
*	66	AVG. DIE. CONSUMPTION	GAL./PTO.HP.-HR.X1000	73
*	67	AVG. PRO. CONSUMPTION	GAL./PTO.HP.-HR.X1000	74
*	68	LOADED TRUCK GASOLINE CONSUMPTION	MI./GAL. X10	75
*	69	EMPTY TRUCK GASOLINE CONSUMPTION	MI./GAL. X10	76
*	70	PWR. REQMT. OF FORAGE BLOWER	HP.-HR./T. W.M.X10	77
*	71	PTO. HP. ON PULL-TYPE FORAGE HARVESTER	P.T.O. HP.	78
*	72	PTO. HP. ON MOWER,MOWERSCONDITIONER	P.T.O. HP.	79
*	73	PTO. HP. ON RAKE	P.T.O. HP.	80
*	74	PTO. HP. ON MOW-CONDITION-WINDROWER UNIT	P.T.O. HP.	81
*	75	PTO. HP. ON BALER	P.T.O. HP.	82
*	76	PTO. HP. ON TRACTOR DRAWN TRANSPORT UNITS	P.T.O. HP.	83
*	77	PTO. HP. ON FORAGE BLOWER	P.T.O. HP.	84
*	80	MAX. NO. OF MEN AT ANY ONE TIME	NUMBER	85
*	81	TOTAL TRANSPORT UNITS	NUMBER	86
*	82	UNUSED STORAGE SPACE	TONS D.M.	87
*	83	ROAD SPEED OF TRANSPORT UNIT LOADED	MI./HR. X10	88
*	84	ROAD SPEED OF TRANSPORT UNIT EMPTY	MI./HR. X10	89
*	85	LINEAR FEET OF HORIZONTAL SILO REQUIRED	FT. X10	90
*	86	CAPACITY - SILAGE VIA FRONT-END LOADER	T.W.M./HR. X10	91
*	87	CAPACITY - SILAGE VIA HOR.-SILO UNLOADER	T.W.M./HR. X10	92
*	89	3 DIGIT RANDOM NUMBER		93
*	90	MAX. NO. OF MEN DURING FIRST CUT.		94

```
* 91     MAX. NO. OF MEN DURING SECOND CUT.
*100     STORAGE FOR A SPECIFIC CLOCK TIME                      DAY OF THE YEAR
* LIST OF FULL-WORD SAVEVALUES :
*    XSAVE1  -- COST OF PURCHASED PROTEIN IN CENTS/T. D.P.
*    XSAVE2  -- COST OF PURCHASED ENERGY IN CENTS/KILOTHERM D.E.
*    XSAVE3  -- MATURITY &/OR WEATHER LOSSES IN CENTS.
*    XSAVE4  -- FIELD LOSSES IN CENTS.
*    XSAVE5  -- STORAGE LOSSES IN CENTS.
*    XSAVE6  -- TOTAL P.A. MACHINERY AND EQUIPMENT COST IN CENTS.
*    XSAVE7  -- TOTAL P.A. MACHINERY OPERATING COST IN CENTS.
*    XSAVE8  -- TOTAL P.A. STORAGE COST IN CENTS.
*    XSAVE9  -- TOTAL P.A. LABOUR COST IN CENTS.
*    XSAVE10 -- TOTAL P.A. DISTRIBUTION COST IN CENTS.
*    XSAVE13 -- TOTAL OUTLAY FOR MACHINERY & EQMT. INCLUDING TRNSPRTS($)
*    XSAVE14 -- TOTAL P.A. F.C. OF WAGONS, WAGON BOXES, ETC. IN CENTS.
*    XSAVE15 -- LOSSES DUE TO UNHARVESTED MATERIAL IN CENTS.
*    XSAVE16 -- TOTAL OUTLAY FOR STORAGE FACILITIES IN DOLLARS.
*    XSAVE17 -- MATURITY LOSS FIGURE IN AC.-% X1000.
*    XSAVE18 -- DIAMETER OF SILO IN FEET.
*    XSAVE19 -- NUMBER OF UNITS OF ITEM .
*    XSAVE20 -- COST OF ITEM(S) IN CENTS OR DOLLARS
*    XSAVE21 -- AMORTIZATION RATE % X10
*    XSAVE22 -- TOTAL REPAIR RATE IN CENTS/HR. OR IN % OF LIST PRICE
*               PER 100 HOURS.
*    XSAVE23 -- HOUSING RATE %
*    XSAVE24 -- P.T.O. HP. OF POWER UNIT
*    XSAVE25 -- WIDTH OF CUT IN FEET X100
*    XSAVE26 -- FIELD OPERATING SPEED M.P.H. X10
*    XSAVE27 -- FIELD EFFICIENCY OF MACHINE IN %
*    XSAVE28 -- AC./HR. X1000 CAPACITY
*    XSAVE29 -- POWER REQUIREMENT HP.-HR./T.DM. X10
*    XSAVE29 -- AVERAGE FUEL CONSUMPTION GAL./PTO.HP.-HR. X1000
*    XSAVE30 -- FUEL COST IN CENTS/GAL. X10
```

```
*    XSAVE31 -- LOAD CAPACITY OF TRANSPORT UNIT TONS X2
*    XSAVE32 -- HITCHING-UNHITCHING TIME MINUTES/LOAD X100
*    XSAVE33 -- UNLOADING TIME MINUTES/TON X1000
*    XSAVE33 -- OR DUMP CYCLE MINUTES/LOAD X100
*    XSAVE33 -- OR UNLOADING TIME MINUTES/LOAD X100
*    XSAVE34 -- MANOEUVERING TIME MINUTES/LOAD X100
*    XSAVE35 -- DRY MATTER DENSITY IN LB./FT.**3
*    XSAVE35 -- OR TRAVELLING TIME IN MINUTES/LOAD X100
*    XSAVE36 -- INITIAL COST PER TRANSPORT UNIT IN CENTS OR DOLLARS
*    XSAVE36 -- OR P.A. FIXED COST PER TRANSPORT UNIT IN CENTS OR $
*    XSAVE38 -- MAXIMUM UNLOADING RATE  MINUTES/LOAD X100
*    XSAVE39 -- MAXIMUM STORING OR PACKING RATE MINUTES/LOAD X100
*    XSAVE40 -- DELAY IN MINUTES ( OF CRITICAL MACHINE)
*    XSAVE41 -- F&C CONVEYOR ELECTRIC DRIVE HP X10
*    XSAVE42 -- STORAGE LOSS IN % D.M.
*    XSAVE43 -- 'WET' MATERIAL TO UNLOAD  TONS W.M. X10
*    XSAVE43 -- OR TONS D.M.X10 FED .
*    XSAVE44 -- AVERAGE BALES PER LOAD TO THE NEAREST BALE
*    XSAVE45 -- STORAGE TIME  MAN-MINUTES/BALE X1000
*    XSAVE46 -- LOADING RATE  MINUTES/LOAD X100
*    XSAVE47 -- YIELD OF CUT IN QUESTION  TONS D.M./ACRE X10
*    XSAVE48 -- COST PER TRANSFERT TRACTOR IN CENTS PER ANNUM
*    XSAVE49 -- TEMPORARY STORAGE FOR VALUES.
*    XSAVE50 -- NUMBER OF PACKING TRACTOR UNITS
*    XSAVE51 -- NUMBER OF TRANSPORTING UNITS - CUT NO. 1
*    XSAVE52 -- LOADS INTO STORAGE NUMBER X10
*    XSAVE53 -- TOTAL HARVESTING TIME IN MINUTES
*    XSAVE54 -- NUMBER OF TRANSPORTING UNITS - CUT NO. 2
*    XSAVE55 -- TOTAL OPERATING TIME OF CRITICAL MACHINE IN MINUTES
*    XSAVE56 -- TOTAL TONS OF WET MATTER STORED X10
*    XSAVE57 -- TOTAL TONS OF DRY MATTER STORED X10
*    XSAVE58 -- AMT. OF CRUDE PROTEIN STORED TO THE NEAREST LB.
*    XSAVE79 -- THE PROBABILITY OF A GOOD DAY X1000.
```

```
*   XSAVE80 -- COLUMN NO. OF CAPACITY MATRIX MH3 .
*   XSAVE81 -- NUMBER OF WORKING HOURS PER DAY
*   XSAVE82 -- ACRES/HOUR X1000
*   XSAVE83 -- RANDOM NO. FOR STARTING SEASON.
*   XSAVE84 -- LENGTH OF GOOD OR BAD PERIOD IN DAYS.
*   XSAVE85 -- TOTAL NUMBER OF DAYS CONSIDERED FOR THIS CUTTING.
*   XSAVE86 -- ACRES LEFT TO DO.
*   XSAVE87 -- ACRES THAT COULD BE DONE IN THE GOOD PERIOD.
*   XSAVE88 -- TOTAL OPERATING HOURS.
*   XSAVE89 -- MAXIMUM NUMBER OF TRANSPORTING UNITS.
*   XSAVE90 -- RANGE, THEN RANDOMLY CHOSEN POINT IN RANGE.
*   XSAVE92 -- LOADS PER DAY.
*   XSAVE93 -- ACRES PER DAY.
*   XSAVE99 -- TEMP. STORAGE OF CHOSEN POINT IN THE RANGE.
*   XSAVE100-- FUNCTION REFERENCE VALUE.
*   XSAVE101-- FUNCTION REFERENCE VALUE.
*   XSAVE102-- FUNCTION REFERENCE VALUE.
*   XSAVE103-- FUNCTION REFERENCE VALUE.
*   XSAVE104-- FUNCTION REFERENCE VALUE.
*   XSAVE105-- CUTTING WIDTH IN FEET X100
*   XSAVE106-- CUTTING UNIT P.T.O. HP.
*   XSAVE107-- STD. AC./HR. X1000 OF CUTTING UNIT.
*   XSAVE108-- OPERATING COST OF CUTTING UNIT IN CENTS/HR.
*   XSAVE109-- MINUTES CUTTING.
*   XSAVE110-- MINUTES RAKING.
*   XSAVE111-- REPAIR RATE - TEMPORARY OR FOR TRANSPORTS IN CENTS/HR.
*   XSAVE118-- CURRENT D.C.P.  %X10
*   XSAVE119-- CURRENT DIGESTIBLE ENERGY  KCAL./LB. D.M. BASIS.
*   XSAVE120-- EQUIVALENT MATURITY LOSS IN TONS D.M. X10 .
* LIST OF MATRIX SAVEVALUE 1 VECTOR SPACES :
* ALL COSTS AND LOSSES ARE GIVEN IN CENTS UNLESS OTHERWISE STATED.
*  MXSAVE1 (1,1 ) -- TRANSACTION NUMBER.
*  MXSAVE1 (1,2-16)- NETWORK NODE NUMBERS.
```

```
*   MXSAVE1 (1,17) -- P.A. F.C. OF EQMT. LESS TRKS,TRCTRS, & WAGONS.
*   MXSAVE1 (1,18) -- NET TONS W.M./LOAD X2 .
*   MXSAVE1 (1,19) -- EFFECTIVE MATURITY LOSS TONS D.M. X10 .
*   MXSAVE1 (1,20) -- TONS OF DRY MATTER STORED X10.
*   MXSAVE1 (1,21) -- TONS OF DRY MATTER FED X10.
*   MXSAVE1 (1,22) -- POUNDS OF DIGESTIBLE PROTEIN STORED.
*   MXSAVE1 (1,23) -- POUNDS OF DIGESTIBLE PROTEIN FED.
*   MXSAVE1 (1,24) -- MAXIMUM NUMBER OF MEN(1).
*   MXSAVE1 (1,25) -- MAXIMUM NUMBER OF MEN(2).
*   MXSAVE1 (1,26) -- ACRES NOT HARVESTED(1).
*   MXSAVE1 (1,27) -- ACRES NOT HARVESTED(2).
*   MXSAVE1 (1,28) -- DAYS TO HARVEST(1).
*   MXSAVE1 (1,29) -- DAYS TO HARVEST(2).
*   MXSAVE1 (1,30) -- STANDARD MINUTES PER MAN DURING HARVESTING(1).
*   MXSAVE1 (1,31) -- STANDARD MINUTES PER MAN DURING HARVESTING(2).
*   MXSAVE1 (1,32) -- TOTAL OPERATING MINUTES OF HARVESTER UNIT.
*   MXSAVE1 (1,33) -- TOTAL OPERATING MINUTES OF CUTTING UNIT.
*   MXSAVE1 (1,34) -- TOTAL OPERATING MINUTES OF RAKING UNIT.
*   MXSAVE1 (1,35) -- TOTAL OPERATING MINUTES OF FORAGE BLOWER.
*   MXSAVE1 (1,36) -- TOTAL OPERATING MINUTES OF PACKING &/OR UNLOADING.
*   MXSAVE1 (1,37) -- TOTAL OPERATING MINUTES OF TRANSPORT UNIT(S).
*   MXSAVE1 (1,38) -- PER ANNUM FIXED COST OF TRACTOR ON HARVESTER.
*   MXSAVE1 (1,39) -- PER ANNUM FIXED COST OF TRACTOR ON CUTTING/RAKING.
*   MXSAVE1 (1,40) -- PER ANNUM FIXED COST OF TRACTOR ON FORAGE BLOWER.
*   MXSAVE1 (1,41) -- P.A.F.C. OF TRACTOR ON PACKING &/OR UNLOADING UNIT
*   MXSAVE1 (1,42) -- P.A.F.C. OF TRCTR. OR TRUCK ON TRANSPORT UNIT(S).
*   MXSAVE1 (1,43) -- CUSTOM CHARGES FOR TRANSPORT UNITS.
*   MXSAVE1 (1,44) -- TOTAL OUTLAY FOR ALL MACH. & EQMT. (DOLLARS).
*   MXSAVE1 (1,45) -- TOTAL OUTLAY FOR ALL FORAGE-STORAGE FACILITIES($).
*   MXSAVE1 (1,46) -- TOTAL PER ANNUM FIXED COST OF ALL MCH. & EQMT.
*   MXSAVE1 (1,47) -- TOTAL PER ANNUM OPERATING COST OF MACH. & EQMT.
*   MXSAVE1 (1,48) -- TOTAL PER ANNUM FIXED COST OF STORAGE FACILITIES.
*   MXSAVE1 (1,49) -- TOTAL PER ANNUM LABOUR COST.
```

```
*  MXSAVE1 (1,50) -- TOTAL PER ANNUM DISTRIBUTION COST.
*  MXSAVE1 (1,51) -- MATURITY AND/OR WEATHER LOSSES.
*  MXSAVE1 (1,52) -- FIELD LOSSES.
*  MXSAVE1 (1,53) -- STORAGE LOSSES.
*  MXSAVE1 (1,54) -- LOSSES DUE TO UNHARVESTED ACRES.
*  MXSAVE1 (1,55) -- MAXIMUM NUMBER OF TRANSPORTING UNITS USED.
*  MXSAVE1 (1,56) -- NUMBER OF TRACTORS PACKING &/OR UNLOADING.
*  MXSAVE1 (1,57) -- TOTAL PER ANNUM COST(FIELD TO EXIT FROM STORAGE).
*  MXSAVE1 (1,58) -- TOTAL P.A. COST IN DOLLARS / TON D.P. FED
* LIST OF LOGIC SWITCHES :
* NO.           MODE R                          MODE S
*  1   DIRECT-CUT                        PRE-CUT
*  2   HIGH MOISTURE SILAGE              DEHYDRATED ALFALFA
*  3   TRACTOR POWER                     TRUCK POWER
*  4   SIDE-UNLDG.SELF-UNLDG. UNIT       DUMP UNIT
*  5   MOWER,RAKE SEQUENCE               MOWER,CONDITNR.,RAKE SEQUENCE
*  6   WINDROWED W/O A RAKE              RAKE ALREADY PURCHASED
*  7   WILTED GRASS SILAGE               HAYLAGE
*  8   FORAGE BLOWER                     FLIGHT AND CHAIN CONVEYOR
*  9   PULL-TYPE BALER                   SELF-PROPELLED BALER
* 10   BALE THROWER                      MANNED BALE WAGONS
* 11   FIRST CUTTING OF ALFALFA          SECOND CUTTING OF ALFALFA
* 12   RANDOM STACK BALES                MANUALLY STACK BALES
* 13   'BAD' PERIOD OF WEATHER           'GOOD' PERIOD OF WEATHER
* 14   BALER ONLY                         BALER PLUS ACCUMULATOR
* 20   HIRED TRANSPORT POWER              OWNED TRANSPORT POWER
*
* LIST OF PARAMETERS :
*   NO.          DESCRIPTION
*   --           -----------
*   01           NEXT BLANK COLUMN INDICATOR FOR MX1.
*   02           LOOP PARAMETER.
*   03           GOOD DAYS USED , ACCUMULATOR.
```

```
*   07             MATRIX REFERENCE NUMBER FOR TRACTORS.
*   08             MATRIX REFERENCE NUMBER.
*   09             LABEL OF SAVEXH BEING INITIALIZED.
*   10             MAINLINE BLOCK LABEL FOR SUBROUTINE RNGEN.
*   11             MATRIX REFERENCE NUMBER.
*   12             INDICATOR OF TYPE OF CUTTING METHOD USED.
*   13             SAVEVALUE REFERENCE NUMBER.
*   14             MAINLINE BLOCK LABEL FOR SBR. BWTHR,SWTHR.
*   15             MAINLINE BLOCK LABEL FOR SEVERAL SUBROUTINES.
*   16             CAPACITY MATRIX LABEL.
*   17             WEATHER FUNCTION NUMBER -- BAD  PERIODS.
*   18             WEATHER FUNCTION NUMBER -- GOOD PERIODS.
*  MATRIX  MX2
*   COLNO01 -- MULTIPLE OF UNITS USED IN X-COLUMNS
*   COLNO02 -- MINIMUM OF X
*   COLNO03 -- MAXIMUM OF X
*   COLNO04 -- MEAN OF X
*   COLNO05 -- STANDARD DEVIATION OF X
*   COLNO06 -- MINIMUM OF Y
*   COLNO07 -- MAXIMUM OF Y
*   COLNO08 -- MEAN OF Y
*   COLNO09 -- STANDARD DEVIATION OF Y
*   COLNO10 -- REGRESSION INTERCEPT A  IN CENTS
*   COLNO11 -- REGRESSION COEFFICIENT B  IN CENTS
*   COLNO12 -- STANDARD ERROR OF B  IN CENTS
*   COLNO13 -- ZERO-INTERCEPT LINEAR APPROXIMATION S  IN CENTS
*   COLNO14 -- AMORTIZATION RATE IN % X10
*   COLNO15 -- TOTAL REPAIR RATE % OF LIST PRICE PER 100 HOURS
*   ROWNO01 -- FARM WAGONS(RUNNING GEAR LESS TIRES) - TONS PAYLOAD
*   ROWNO02 -- SELF-UNLOADING FORAGE BOXES - CU.FT. CAPACITY
*   ROWNO03 -- FARM TRUCKS(CHASSIS) - TONS PAYLOAD
*   ROWNO04 -- CUSTOM TRUCK BOXES INSTALLED - NEAREST CU.FT.
*   ROWNO05 -- GASOLINE TRACTORS - P.T.O. HP.
```

```
*   ROWNO06 -- DIESEL TRACTORS - P.T.O. HP.
*  MATRIX  MH3
*   ROWS 1-5 IN AC./HR. X1000 .
*   ROWS 6-9 IN TONS W.M./HR. X100.
*   ROWNO01 -- MOWER
*   ROWNO02 -- SIDE-DELIVERY RAKE
*   ROWNO03 -- SELF-PROPELLED WINDROWER
*   ROWNO04 -- MULTI-TREATMENT MACHINE
*   ROWNO05 -- FORAGE HARVESTER
*   ROWNO06 -- LIGHT WEIGHT BALER ONLY
*   ROWNO07 -- LIGHT WEIGHT BALER PLUS WAGON
*   ROWNO08 -- HEAVY DUTY BALER ONLY
*   ROWNO09 -- HEAVY DUTY BALER PLUS WAGON
*   COLNO01 -- LOW SPEED/LOW FIELD EFFICIENCY (ROWS 1 - 5)
*   COLNO01 -- LOW CAPACITY/LOW FIELD EFFICIENCY (ROWS 6 TO 9)
*   COLNO02 -- LOW SPEED/HIGH FIELD EFFICIENCY (ROWS 1 - 5)
*   COLNO02 -- LOW CAPACITY/HIGH FIELD EFFICIENCY (ROWS 6 TO 9)
*   COLNO03 -- HIGH SPEED/LOW FIELD EFFICIENCY (ROWS 1 - 5)
*   COLNO03 -- HIGH CAPACITY/LOW FIELD EFFICIENCY (ROWS 6 TO 9)
*   COLNO04 -- HIGH SPEED/HIGH FIELD EFFICIENCY (ROWS 1 - 5)
*   COLNO04 -- HIGH CAPACITY/HIGH FIELD EFFICIENCY (ROWS 6 TO 9)
*  MATRIX  MH5
*   COLNO01 -- MINIMUM SPEED M.P.H. X10 FULL
*   COLNO02 -- MAXIMUM SPEED M.P.H. X10 FULL
*   COLNO04 -- MINIMUM SPEED M.P.H. X10 EMPTY
*   COLNO05 -- MAXIMUM SPEED M.P.H. X10 EMPTY
*   ROWNO01 -- FORAGE TRANSPORT UNITS - TRACTOR POWER
*   ROWNO02 -- FORAGE TRANSPORT UNITS - TRUCK POWER
*  MATRIX  MH7
*   ROWNO01 TO ROWNO3 -- FLAIL FORAGE HARVESTERS
*   ROWNO04 TO ROWNO7 -- FLYWHEEL-TYPE FORAGE HARVESTERS
*   ROWNO08 TO ROWNO10-- CYLINDER-TYPE FORAGE HARVESTERS
*   ROWNO11 TO ROWNO12-- SP FORAGE HARVESTERS WITH CUTTER BAR AS ABOVE
```

```
*   ROWNO13 TC ROWNC16-- HORIZONTAL SILO UNLCADERS
*   ROWNO17 TO ROWNO20-- SP WINDROWERS LESS CONDITIONERS
*   ROWNO21 TC ROWNC24-- SP WINDROWERS PLUS CONDITIONERS
*   ROWNO25 TC ROWNC26-- FRONT-END LCADERS WITH 60''BUCKET & TINES.
*   ROWNO27           -- SIDE-TIP WAGON.
*   ROWNO28           -- LARGE FRONT-END LOADER SCOOP(21 CU.FT.)
*   COLNO01 -- INITIAL COST IN DOLLARS.
*   CCLNO02 -- WIDTH OF CUT IN FEET X100 (ROWS 1 - 12) (17-24)
*   COLNO02 -- HEIGHT OF CUT IN FEET (ROWS 13 - 16)
*   COLNO03 -- P.T.O. HP. OF POWER UNIT(ROWS 11 & 12) (17-24)
*   COLNO03 -- RANGE OF REFERENCE NO. OF HORZ. SILOS(ROWS 13 - 16)
*   COLNO04 -- PER ANNUM FIXED COST IN DOLLARS.
*   CCLNO05 -- REPAIR COST IN CENTS/HOUR.
* TENTHS-HP.,3 PHASE ,60 CYCLE ELECTRIC MOTORS--1800 R.P.M. -DRIP-PROOF
     1 FUNCTION   X101,D19
10    56    15    63    20    69    30    81    50    104   75    129
100   154   150   203   200   233   250   280   300   319   400   483
500   532   600   733   750   884   1000  1155  1250  1395  1500  2016
2000  2595
* TENTHS-HP. 3 PH.,60 CYC.,1800 R.P.M.,TOT.ENCLOSED,FAN-COOLED
     2 FUNCTION   X101,D19
10    75    15    83    20    89    30    108   50    137   75    171
100   205   150   323   200   388   250   480   300   544   400   957
500   1157  600   1504  750   1909  1000  2399  1250  3100  1500  3528
2000  4544
* TENTHS-HP. 3 PH.,60 CYC.,1800 R.P.M.,TOT.ENCLOSED,EXPL.PROOF
     3 FUNCTION   X101,D19
10    122   15    132   20    141   30    173   50    213   75    291
100   325   150   465   200   530   250   681   300   745   400   1163
500   1355  600   1698  750   2158  1000  2658  1250  3459  1500  3891
2000  5041
* FULL H.P.  2 CYCLE GASOLINE ENGINE (NEAREST $5.)
     4 FUNCTION   X102,D10
```

```
2     65    3     65    4     70    5     75    6     105   7     110
8     160   9     215   10    285   18    590
* 100THS HP. 60 CYCLE ELECTRIC MOTORS-S.P. (NEAREST $5.)
    5 FUNCTION    X102,D6
25    40    33    50    50    65    75    80    100   100   150   120
* %M.C. VS. FIELD LOSSES % D.M.          HERMETICALLY-SEALED TOWER SILO.
* UNSEALED TOWER SILO, AND SEALED BUNKER SILO.
    6 FUNCTION    XH10,D8
40    13    50    10    60    6     65    4     70    3     75    3
80    2     85    2
*  % M.C. VS. SEEPAGE,FERMENTATION,SURFACE LOSSES % D.M.
    7 FUNCTION    XH10,D8
40    7     50    6     60    6     65    6     70    8     75    11
80    16    85    20
* INITIAL OR LOWEST INITIAL VALUES OF SAVEXH ENTITIES. LIST NUMBER
* SUBJECT TO CHANGE. NOTE: HORIZONTAL SILOS ONLY FILLED ONCE A YEAR.
* D.P. AND D.E. FIGURES FOR FORAGE AT THE OPTIMAL POINT OF GROWTH ARE
* TAKEN FROM N.R.C. TABLES -- ALFALFA HAY, PRE-BLOOM -- CHANGING THE
* BASIS FROM 89% D.M. TO 100% D.M.
    8 FUNCTION    XH99,L73
     11200      95        60        431       124       1560
     1620       149       1228      10        12        25
     30         0         300       10        1         10
     600        200       125       215       180       140
     775        104       105       105       0         8
     5          1         100       150       50        25
     10         125       300       400       800       35
     15         33        0         50        40        55
     72         75        75        75        65        55
     50         40        60        6         8         18
     20         50        50        0         76        55
     91         0         0         10        80        35
     35         35        35        35        60        0
```

```
     9 FUNCTION    XH10,D6
6)      14      65      13      70      12      75      15      80      19      85      23
* RANGES THAT SAVEXF ENTITIES CAN TAKE OVER AND ABOVE VALUES IN FN8.
* LIST NUMBER SUBJECT TO CHANGE.
* THE '12' IN NO. 58 IS TO INSURE <=9.T. PER GROSS TRUCK LOAD, SINCE
* THE SIDE-TIP WAGON IS LIMITED TO APPROXIMATELY 8.T. W.M. CAPACITY,
* AND THE TRUCK BODY CAN BE ROUGHLY ESTIMATED AT 1. T.
    10 FUNCTION    XF99,L78
      0            0            0            0            0            0
      0            0            0            0            0            0
      0            10           0            0            0            0
      0            0            0            0            0            0
      0            21           48           35           0            0
      0            0            0            0            0            0
      0            0            0            20           10           15
      31           13           0            35           10           15
      8            10           10           15           15           15
      15           20           20           12           8            4
      30           50           10           0            25           27
      30           0            0            5            40           15
      15           15           15           15           40           0
* % M.C. VS. SEEPAGE, FERMENTATION,SURFACE LOSSES % D.M.
    11 FUNCTION    XH10,D5
65      14      70      12      75      13      80      17      85      21
*  PAGE 234 PICHEY--%M.C.(W.B.)VS. F SUBM X10--FIGURE FOR 80% EXTRAPLTD
    12 FUNCTION    XH10,C5
40      55      50      62      60      63      70      65      80      67
* FLIGHT-&-CHAIN CONVEYOR - 62' LONG, 1' HEIGHT ALLOWED FOR CLEARANCE,
* 3'' X 21'' X 14'' FLIGHT; VOLUME PER FLIGHT (FT.**3  X1000)
* MAXIMUM FLIGHT VOLUME OF LEVEL FULL FLIGHT (ARBITRARILY ASSUMED)
    21 FUNCTION    X103,L37          ANGLE OF REPOSE = 40 DEGREES.
      510          364          204          510          364          204
      204          490          343          204          117          490
```

```
   343        204        117        204        117        204
   490        204        490        204        490        204
   490        204        510        490        257        107
   510        490        257        107        510        510
   510
  22 FUNCTION   X103,L37        ANGLE OF REPOSE = 50 DEGREES.
   510        510        406        510        510        406
   406        510        510        406        204        510
   510        406        204        406        204        406
   510        406        510        406        510        406
   510        406        510        510        469        179
   510        510        469        179        510        510
   510
  23 FUNCTION   X103,L37        ANGLE OF REPOSE = 60 DEGREES.
   510        510        510        510        510        510
   510        510        510        510        406        510
   510        510        406        510        406        510
   510        510        510        510        510        510
   510        510        510        510        510        364
   510        510        510        364        510        510
   510
* MAXIMUM FLIGHT VOLUME OF 120% OF LEVEL FULL FLIGHT (ARBITRARY )
  24 FUNCTION   X103,L37        ANGLE OF REPOSE = 40 DEGREES.
   587        427        204        587        427        204
   204        490        343        204        117        490
   343        204        117        204        117        204
   490        204        490        204        490        204
   490        204        587        490        257        107
   587        490        257        107        587        587
   587
  25 FUNCTION   X103,L37        ANGLE OF REPOSE = 50 DEGREES.
   587        587        406        587        587        406
   406        587        587        406        204        587
```

```
     587          406          204          406          204          406
     587          406          587          406          587          406
     587          406          587          587          469          179
     587          587          469          179          587          587
     587
    26 FUNCTION   X103,L37          ANGLE OF REPOSE = 60 DEGREES.
     587          587          587          587          587          587
     587          587          587          587          587          406
     587          587          587          406          587          406
     587          587          587          587          587          587
     587          587          587          587          587          364
     587          587          587          364          587          587
     587
    27 FUNCTION   X103,L37          HORIZONTAL CONVEYING DISIANCE FT.X10
     482          420          357          482          420          357
     357          472          414          357          261          472
     414          357          261          357          261          357
     472          357          472          357          472          357
     472          357          528          472          383          242
     528          472          383          242          550          550
     550
* HORIZ. PIT SILCS--INITIAL CCST (CENTS) PER LINEAR FOCT OF SILO

    28 FUNCTION   X104,L36
     1720         1930         2281         2631         2982         3332
     3652         2369         2668         3040         3413         3735
     4158         3066         3461         3856         4251         4646
     4200         4542         4971         5399         5827         5015
     5466         5916         6366         6817         7261         7766
     8272         8778         9802         10364        10925        11487
* HORIZ. PIT SILCS--POLYTHENE P.A. COST (CENTS) PER LINEAR FOOT OF SILO
    29 FUNCTION   X104,L36
     23           26           32           38           44           50
     56           29           34           40           46           52
```

```
     58          36          42          48          54          60       491
     45          50          56          62          68          52       492
     58          64          70          76          68          74       493
     80          86          84          90          96         102       494
* HORIZ. PIT SILOS--NEAREST CU.FT./LINEAR FOOT OF SILO                    495
    30 FUNCTION   X104,L36                                                496
     84         102         132         162         192         222       497
    252         149         181         221         261         301       498
    341         233         283         333         383         433       499
    394         446         511         576         641         525       500
    600         675         750         825         933        1033       501
   1133        1233        1458        1583        1708        1833       502
* HORIZ. PIT SILOS--INSIDE BOTTOM WIDTH OF SILO IN FEET                   503
*                    6', 8', 10', 13', 15', 20', AND 25' DEPTHS           504
    31 FUNCTION   X104,L36                                                505
     12          15          20          25          30          35       506
     40          16          20          25          30          35       507
     40          20          25          30          35          40       508
     26          30          35          40          45          30       509
     35          40          45          50          40          45       510
     50          55          50          55          60          65       511
* RUTLEDGE TRACTABILITY CRITERIA -- MEDIUM TO HEAVY SOILS.                512
*  JUNE 20 THROUGH JULY 15                                                513
    32 FUNCTION   RN2,C10          BAD DAYS P=0.320                       514
0      0      .396  1      .631  2      .758  3      .852  4      .926  5 515
.960   6      .973  7      .993  8      1.000 9                          516
    33 FUNCTION   RN3,C18          GOOD DAYS G=0.680                      517
0      0      .163  1      .372  2      .512  3      .634  4      .698  5 518
.756   6      .808  7      .843  8      .890  9      .913  10     .936  11 519
.959   12     .977  13     .985  15     .988  17     .994  19     1.000 20 520
* RUTLEDGE TRACTABILITY CRITERIA -- MEDIUM TO HEAVY SOILS.                521
*  AUGUST 15 THROUGH SEPTEMBER 18                                         522
    34 FUNCTION   RN2,C16          BAD DAYS P=0.324                       523
```

```
0       0       .417  1       .564  2       .679  3       .782  4       .821  5
.859    6       .917  7       .936  8       .962  9       .968  11      .974  12
.981    15      .987  16      .994  19      1.000 20
    35 FUNCTION   RN3,C22              GOOD DAYS Q=0.676
0       0       .151  1       .252  2       .365  3       .484  4       .541  5
.604    6       .660  7       .704  8       .723  9       .792  10      .843  11
.868    12      .893  13      .912  14      .918  15      .925  16      .943  18
.962    20      .975  22      .987  23      1.000 26
* INITIALIZE ALL MATRICES.
* INITIALIZE HALF-WORD MATRIX NO. 1.
     1 MATRIX      H,4,3                WAGONS,TRUCKS,S-U BOXES, DUMP BOXES.
       INITIAL     MH1(1-2,1),510/MH1(3-4,1),75
       INITIAL     MH1(1,2),59/MH1(1,3),270/MH1(2,2),181/MH1(2,3),61
       INITIAL     MH1(3,2),59/MH1(3,3),270/MH1(4,2),181/MH1(4,3),61
* INITIALIZE FULL-WORD MATRIX NO. 2.
     2 MATRIX      X,6,15               MAJOR MACHINERY MATRIX.
       INITIAL     MX2(1,1),2/MX2(1,2),6/MX2(1,3),15/MX2(1,4),10
       INITIAL     MX2(1,5),3/MX2(1,6),13450/MX2(1,7),28000
       INITIAL     MX2(1,8),19182/MX2(1,9),4674/MX2(1,10),4017
       INITIAL     MX2(1,11),2908/MX2(1,12),580/MX2(1,13),3680
       INITIAL     MX2(1,14),150/MX2(1,15),2
       INITIAL     MX2(2,1),1/MX2(2,2),293/MX2(2,3),700/MX2(2,4),477
       INITIAL     MX2(2,5),139/MX2(2,6),75000/MX2(2,7),240000
       INITIAL     MX2(2,8),176788/MX2(2,9),48491/MX2(2,10),111414
       INITIAL     MX2(2,11),137/MX2(2,12),113/MX2(2,13),370
       INITIAL     MX2(2,14),150/MX2(2,15),2
       INITIAL     MX2(3,1),2/MX2(3,2),3/MX2(3,3),25/MX2(3,4),10
       INITIAL     MX2(3,5),6/MX2(3,6),345700/MX2(3,7),940000
       INITIAL     MX2(3,8),495657/MX2(3,9),163164/MX2(3,10),254550
       INITIAL     MX2(3,11),45789/MX2(3,12),7074/MX2(3,13),94053
       INITIAL     MX2(3,14),150/MX2(3,15),2
       INITIAL     MX2(4,1),1/MX2(4,2),154/MX2(4,3),823/MX2(4,4),445
       INITIAL     MX2(4,5),159/MX2(4,6),31000/MX2(4,7),81500
```

```
         INITIAL    MX2(4,8),52625/MX2(4,9),12146/MX2(4,10),20822
         INITIAL    MX2(4,11),71/MX2(4,12),3/MX2(4,13),118
         INITIAL    MX2(4,14),150/MX2(4,15),2
         INITIAL    MX2(5,1),1/MX2(5,2),26/MX2(5,3),66/MX2(5,4),43
         INITIAL    MX2(5,5),11/MX2(5,6),350000/MX2(5,7),825000
         INITIAL    MX2(5,8),512533/MX2(5,9),151316/MX2(5,10),-39973
         INITIAL    MX2(5,11),12658/MX2(5,12),1384/MX2(5,13),11742
         INITIAL    MX2(5,14),150/MX2(5,15),1
         INITIAL    MX2(6,1),1/MX2(6,2),27/MX2(6,3),131/MX2(6,4),65
         INITIAL    MX2(6,5),27/MX2(6,6),377500/MX2(6,7),1685000
         INITIAL    MX2(6,8),814926/MX2(6,9),341358/MX2(6,10),24964
         INITIAL    MX2(6,11),12106/MX2(6,12),669/MX2(6,13),12487
         INITIAL    MX2(6,14),150/MX2(6,15),1
* INITIALIZE HALF-WORD MATRIX NO. 3.
       3 MATRIX     H,9,4                CAPACITY FIGURES.
         INITIAL    MH3(1,1),318/MH3(1,2),361/MH3(1,3),500/MH3(1,4),505
         INITIAL    MH3(2,1),318/MH3(2,2),382/MH3(2,3),455/MH3(2,4),545
         INITIAL    MH3(3,1),318/MH3(3,2),361/MH3(3,3),409/MH3(3,4),464
         INITIAL    MH3(4,1),318/MH3(4,2),361/MH3(4,3),500/MH3(4,4),565
         INITIAL    MH3(5,1),200/MH3(5,2),300/MH3(5,3),279/MH3(5,4),419
         INITIAL    MH3(6,1),130/MH3(6,2),160/MH3(6,3),325/MH3(6,4),400
         INITIAL    MH3(7,1),110/MH3(7,2),140/MH3(7,3),275/MH3(7,4),350
         INITIAL    MH3(8,1),325/MH3(8,2),400/MH3(8,3),650/MH3(8,4),800
         INITIAL    MH3(9,1),275/MH3(9,2),350/MH3(9,3),550/MH3(9,4),700
* INITIALIZE HALF-WORD MATRIX NO. 6.
       6 MATRIX     H,2,6                TRANSIT SPEED FIGURES.
         INITIAL    MH6(1,1),80/MH6(1,2),150/MH6(1,3),0
         INITIAL    MH6(1,4),100/MH6(1,5),200/MH6(1,6),0
         INITIAL    MH6(2,1),200/MH6(2,2),300/MH6(2,3),0
         INITIAL    MH6(2,4),250/MH6(2,5),400/MH6(2,6),0
* INITIALIZE HALF-WORD MATRIX NO. 7.
* P.A.F.C. CALCULATED ON BASIS OF 8% INTEREST, 0.5% INSURANCE,
* 1% HOUSING,  AND THE AMORTIZATION  RATE AS ALLOWED FOR FARM INCOME
```

```
* TAX PURPOSES.
      7 MATRIX      H,28,5            INDIVIDUAL MACHINES.
        INITIAL     MH7(1,1),1850/MH7(1,2),600/MH7(1,3),0
        INITIAL     MH7(2,1),1942/MH7(2,2),600/MH7(2,3),0
        INITIAL     MH7(3,1),1776/MH7(3,2),500/MH7(3,3),0
        INITIAL     MH7(4,1),3316/MH7(4,2),600/MH7(4,3),0
        INITIAL     MH7(5,1),4282/MH7(5,2),800/MH7(5,3),0
        INITIAL     MH7(6,1),4739/MH7(6,2),800/MH7(6,3),0
        INITIAL     MH7(7,1),4595/MH7(7,2),750/MH7(7,3),0
        INITIAL     MH7(8,1),5200/MH7(8,2),650/MH7(8,3),0
        INITIAL     MH7(9,1),5782/MH7(9,2),1000/MH7(9,3),0
        INITIAL     MH7(10,1),4727/MH7(10,2),600/MH7(10,3),0
        INITIAL     MH7(11,1),17145/MH7(11,2),700/MH7(11,3),148
        INITIAL     MH7(12,1),17940/MH7(12,2),1000/MH7(12,3),148
        INITIAL     MH7(13,1),2654/MH7(13,2),13/MH7(13,3),22
        INITIAL     MH7(14,1),2586/MH7(14,2),13/MH7(14,3),22
        INITIAL     MH7(15,1),2576/MH7(15,2),15/MH7(15,3),27
        INITIAL     MH7(16,1),2730/MH7(16,2),20/MH7(16,3),31
        INITIAL     MH7(17,1),3315/MH7(17,2),1200/MH7(17,3),53
        INITIAL     MH7(18,1),3400/MH7(18,2),1400/MH7(18,3),35
        INITIAL     MH7(19,1),4120/MH7(19,2),1500/MH7(19,3),38
        INITIAL     MH7(20,1),3544/MH7(20,2),1350/MH7(20,3),37
        INITIAL     MH7(21,1),4392/MH7(21,2),1500/MH7(21,3),53
        INITIAL     MH7(22,1),4520/MH7(22,2),1500/MH7(22,3),38
        INITIAL     MH7(23,1),5520/MH7(23,2),800/MH7(23,3),28
        INITIAL     MH7(24,1),4634/MH7(24,2),1350/MH7(24,3),38
        INITIAL     MH7(25,1),1150/MH7(26,1),1210/MH7(27,1),3250
        INITIAL     MH7(28,1),160/MH7(25-28,2-3),0
        INITIAL     MH7(1,4),361/MH7(2,4),379/MH7(3,4),346/MH7(4,4),647
        INITIAL     MH7(5,4),635/MH7(6,4),924/MH7(7,4),396
        INITIAL     MH7(8,4),1014/MH7(9,4),1128/MH7(10,4),922
        INITIAL     MH7(11,4),4201/MH7(12,4),4395/MH7(13,4),518
        INITIAL     MH7(14,4),504/MH7(15,4),502/MH7(16,4),532
```

```
          INITIAL     MH7(17,4),812/MH7(18,4),833/MH7(19,4),1009
          INITIAL     MH7(20,4),868/MH7(21,4),1076/MH7(22,4),1107
          INITIAL     MH7(23,4),1352/MH7(24,4),1135/MH7(25,4),224
          INITIAL     MH7(26,4),236/MH7(27,4),796/MH7(28,4),31
          INITIAL     MH7(1,5),74/MH7(2,5),78/MH7(3,5),71/MH7(4,5),133
          INITIAL     MH7(5,5),171/MH7(6,5),190/MH7(7,5),184/MH7(8,5),208
          INITIAL     MH7(9,5),231/MH7(10,5),189/MH7(11,5),514
          INITIAL     MH7(12,5),538/MH7(13,5),133/MH7(14,5),129
          INITIAL     MH7(15,5),129/MH7(16,5),136/MH7(17,5),153
          INITIAL     MH7(18,5),136/MH7(19,5),165/MH7(20,5),142
          INITIAL     MH7(21,5),176/MH7(22,5),181/MH7(23,5),221
          INITIAL     MH7(24,5),185/MH7(25,5),28/MH7(26,5),29/MH7(27,5),65
          INITIAL     MH7(28,5),4
        1 MATRIX      X,1,58            TRANSACTIONS VECTOR.
 * INITIALIZE SOME HALF-WORD SAVEVALUES AND ZERO ALL FULL-WORD VALUES.
          INITIAL     XH90-XH120,0/X1-X120,0
2         ADVANCE     2,2
3         TERMINATE
 * THIS INITIALIZATION PATH IS A METHOD OF CHANGING THE INITIAL RANDOM
 * NUMBER SEED BY VARYING THE NUMBER OF TRANSACTIONS THROUGH THIS PATH.
4         GENERATE    365,,,2000,,100,F
5         TEST E      N4,K1,RANGE
 * INITIALLY,ALL LOGIC SWITCHES ARE AUTOMATICALLY RESET UNLESS OTHERWISE
 * SPECIFIED.
 * INITIALIZE SOME HALF-WORD SAVEVALUES.
6 START   SAVEVALUE   99+,K1,H          INCREMENT SAVEXH NO. COUNTER.
7         ASSIGN      9,XH99
8         SAVEVALUE   *9,FN8,H          INITIAL VALUE
9         TEST E      P9,K44,START
  1       FVARIABLE   XH1-(XH2*XH5/XH4)*2000/XH3+1/2
  2       FVARIABLE   XH1*1000/XH4+1/2
  3       FVARIABLE   (1000000*XH2/XH3-XH5*X1/2)/XH7+1/2
  4       FVARIABLE   (MX2(*8,10)+MX2(*8,11)*(X31+2)*10*(100-XH10)/X35)/100
```

```
   5      FVARIABLE   (MX2(*8,10)+MX2(*8,11)*(X31+2)/2)/100+1/2
   6      FVARIABLE   (MX2(*7,10)+X49*MX2(*7,11))/100+1/2
   7      FVARIABLE   X20*(XH34/10+XH30+XH31/10+XH32)/100+1/2
   8      FVARIABLE   X19*X36
   9      FVARIABLE   X19*X36*(X21/10+XH30+XH31/10+XH32)+1/2
   10     FVARIABLE   X20*(X21/10+XH30+XH31/10+X23)+1/2
   13     FVARIABLE   X20*(100-XH14)/100+1/2
   100    FVARIABLE   X20*(100-XH14)
 * FIND COST OF PROTEIN AND ENERGY.
10        TEST G      XH6,K0,UREA
11        SAVEVALUE   1,V1                 COST OF PURCHASED PROTEIN
12        TRANSFER    ,SCRSE
13 UREA   SAVEVALUE   1,K0                 FEED GRADE UREA ASCRIBED NO ENERGY
14        SAVEVALUE   1,V2                 COST OF PURCHASED PROTEIN
15 SCRSE  SAVEVALUE   2,K0
16        SAVEVALUE   2,V3                 COST OF PURCHASED ENERGY
 * ESTABLISH VALUES FROM A RANGE OF VALUES, ZERO FULL-WORD SAVEVALUES
 * AND SOME MATRIX SAVEVALUES, AND RESET SOME LOGIC SWITCHES.
17 RANGE  TRANSFER    SBR,INITL,15
18 DICUT  MSAVEVALUE  1,1,2,K2             NETWORK NODE NUMBER.
19        ASSIGN      1,K3                 NEXT COL. OF MX1 TO BE USED.
20        SAVEVALUE   10,XH49,H            % M.C. (W.B.) DIRECT CUT FORAGE
21        TRANSFER    PICK,22,25
22        TRANSFER    ,FLAIL               FRG. HRVSTR. FLAIL-TYPE
23        TRANSFER    ,CYLCB               FRG. HRVSTR. CYL.-TYPE + CUTTER BAR
24        TRANSFER    ,FLYCB               FRG. HRVSTR. FLYWL.-TYPE + CUTTER BAR
25        TRANSFER    ,SPFCE               FRG. HRVSTR. S.P. TYPE + CUTTER BAR
26 DCUT2  TRANSFER    PICK,27,28           TYPE OF TRANSPORT UNIT.
27        TRANSFER    ,OWNED               OWN TRANSPORT UNITS.
28        TRANSFER    ,HIRED               CUSTOM CHARGES FOR TRANSPORT POWER.
29 OWNED  LOGIC S     20
30        MSAVEVALUE  1,1,P1,K51           NETWORK NODE NUMBER.
31        ASSIGN      1+,K1                NEXT COL. OF MX1 TO BE USED.
```

```
32        TRANSFER    PICK,33,36      TYPE OF TRANSPORT UNIT.                    689
33        TRANSFER    ,SUWGN          SIDE-UNLDG.(SELF-UNLDG.) WAGONS            690
34        TRANSFER    ,DPWGN          DUMP WAGONS                                691
35        TRANSFER    ,SUTRK          SIDE-UNLDG.(SELF-UNLDG.) TRUCKS            692
36        TRANSFER    ,DPTRK          DUMP TRUCKS                                693
37  FIRED LOGIC R     20                                                         694
38        MSAVEVALUE  1,1,P1,K52      NETWORK NODE NUMBER.                       695
39        ASSIGN      1+,K1           NEXT COL. OF MX1 TO BE USED.               696
40        TRANSFER    PICK,41,44      TYPE OF TRANSPORT UNIT.                    697
41        TRANSFER    ,SUWGN          SIDE-UNLDG.(SELF-UNLDG.) WAGONS            698
42        TRANSFER    ,DPWGN          DUMP WAGONS                                699
43        TRANSFER    ,STRKH          SIDE-UNLDC.(SELF-UNLDG.) TRUCKS            700
44        TRANSFER    ,DTRKH          DUMP TRUCKS                                701
45  STRKH ASSIGN      11,K3           ROW 3 OF HALF-WORD MATRIX 1.               702
46        MSAVEVALUE  1,1,P1,K73      NETWORK NODE NUMBER.                       703
47        ASSIGN      1+,K1           NEXT COL. OF MX1 TO BE USED.               704
48        LOGIC S     3               INDICATES TRUCK POWER                      705
49        TRANSFER    ,TRK2                                                      706
50  DTRKH ASSIGN      11,K4           ROW 4 OF HALF-WORD MATRIX 1.               707
51        MSAVEVALUE  1,1,P1,K74      NETWORK NODE NUMBER.                       708
52        ASSIGN      1+,K1           NEXT COL. OF MX1 TO BE USED.               709
53        LOGIC S     3               INDICATES TRUCK POWER                      710
54        LOGIC S     4               INDICATES A DUMP UNIT                      711
55        TRANSFER    ,TRK2                                                      712
56  SUWGN ASSIGN      11,K1           ROW 1 OF HALF-WORD MATRIX 1.               713
57        MSAVEVALUE  1,1,P1,K71      NETWORK NODE NUMBER.                       714
58        ASSIGN      1+,K1           NEXT COL. OF MX1 TO BE USED.               715
59        ASSIGN      8,K2                                                       716
60        SAVEVALUE   20,V4                                                      717
61        TRANSFER    ,WGN1                                                      718
62  DPWGN ASSIGN      11,K2           ROW 2 OF HALF-WORD MATRIX 1.               719
63        MSAVEVALUE  1,1,P1,K72      NETWORK NODE NUMBER.                       720
64        ASSIGN      1+,K1           NEXT COL. OF MX1 TO BE USED.               721
```

```
65        LOGIC S     4                INDICATES A DUMP UNIT
66        ASSIGN      8,K4
67        SAVEVALUE   20,V4
68        SAVEVALUE   20+,K550         ADD THE I.C. OF 10.T. HOIST .
69 WGN1   SAVEVALUE   31,XH59          TONS W.M./LOAD X2
70        ASSIGN      8,K1
71        SAVEVALUE   20+,V5           $ INITIAL COST OF WGN. R. GEAR.
72        TRANSFER    ,TPVAL           TRANSPORT UNIT VALUES
73 SUTRK  ASSIGN      11,K3            ROW 3 OF HALF-WORD MATRIX 1.
74        MSAVEVALUE  1,1,P1,K73       NETWORK NODE NUMBER.
75        ASSIGN      1+,K1            NEXT COL. OF MX1 TO BE USED.
76        LOGIC S     3                INDICATES TRUCK POWER
77        ASSIGN      8,K2
78        SAVEVALUE   20,K52           ADD THE I.C. OF P.T.O. INSTALLATION.
79        TRANSFER    ,TRK1
80 DFTRK  ASSIGN      11,K4            ROW 4 OF HALF-WORD MATRIX 1.
81        MSAVEVALUE  1,1,P1,K74       NETWORK NODE NUMBER.
82        ASSIGN      1+,K1            NEXT COL. OF MX1 TO BE USED.
83        LOGIC S     3                INDICATES TRUCK POWER
84        LOGIC S     4                INDICATES A DUMP UNIT
85        ASSIGN      8,K4
86        SAVEVALUE   20,K550          ADD THE I.C. OF 10.T. HOIST .
87 TRK1   SAVEVALUE   31,XH58          TONS W.M./LOAD  X2
88        SAVEVALUE   20+,V4
89        ASSIGN      8,K3
90        SAVEVALUE   20+,V5
91 TRK2   SAVEVALUE   31,XH58          THIS DUPL. REQ'D FOR HIRED TRUCKS.
  * ADD P.A. F.C. OF SIDE TIP WAGON.
92        SAVEVALUE   13+,MH7(27,1)    UPDATE TOTAL OUTLAY FOR MACHINERY.
93        SAVEVALUE   49,X20           TEMPORARY STORAGE OF X20.
94        SAVEVALUE   20,MH7(24,4)     P.A.F.C. IN DOLLARS.
95        SAVEVALUE   14+,V100         PER ANNUM FIXED COST OF TRANSPORTS.
96        SAVEVALUE   20,X49           RETURN ORIGINAL VALUE TO X20.
```

```
 97        SAVEVALUE  22+,MH7(27,5)    REPAIR RATL CENTS/HR.
   * NOTE: TIME OF OPERATION OF SIDE-TIP WAGON IS EQUAL TO THAT OF THE
   * FORAGE HARVESTER.
 98 TPVAL  SAVEVALUE  32,MH1(*11,1)    HITCH-UNHITCH TIME MIN./LD. X100
 99        SAVEVALUE  33,MH1(*11,3)    UNLOADING TIME  MIN./TON X100
   *                                   OR DUMP CYCLE MIN./LOAD X100
100        SAVEVALUE  34,MH1(*11,2)    MANOEUVERING TIME  MIN./LD. X100
101        GATE LR    4,DUMP1          IF A DUMP UNIT, GO TO DUMP1
    20     FVARIABLE  X33*X31/2+1/2
102 SUNL1  SAVEVALUE  33,V20           UNLOADING TIME MIN./LD. X100
103        TRANSFER   ,TRNFC           TRANSPORT FIXED COST - PER UNIT.
104 DUMP1  SAVEVALUE  35,K8            RHO SUB DM APPROXIMATION--A.E.'57
105 TRNFC  GATE LS    20,FHTSP         IF HIRED TRNS. UNITS, GO TO FHTSP.
106        SAVEVALUE  36,V13           $ INITIAL COST PER UNIT.
107        TRANSFER   ,FHTSP
   * FORAGE HARVESTER : TRANSPORT SPEEDS.
108 FHTSP  GATE LR    3,BBB            IF NOT TRACTOR DRAWN, GO TO BBB
   * FIND AVERAGE ROAD SPEED LOADED AND EMPTY FOR TRACTORS WITH FRG. WAGON
109        ASSIGN     11,K1
110        TRANSFER   SBR,SPEED,15
111        TRANSFER   ,FHRD2
   * FIND AVG. ROAD SPEED LOADED AND EMPTY FOR TRUCKS WITH FORAGE BOXES.
112 BBB    ASSIGN     11,K2
113        TRANSFER   SBR,SPEED,15
114        TRANSFER   ,FHRD2
115 FHRD2  TRANSFER   ,DRAT2           DIR-CUT RATE DETERMINATION 2
116 FLAIL  ASSIGN     8,K1             LOWEST MATRIX ROW NUMBER.
117        MSAVEVALUE 1,1,P1,K21       NETWORK NODE NUMBER.
118        ASSIGN     1+,K1            NEXT COL. OF MX1 TO BE USED.
119        SAVEVALUE  90,K2            RANGE OF MATRIX ROW NOS.
120        TRANSFER   ,CBFC1
121 CYLCH  ASSIGN     8,K8             LOWEST MATRIX ROW NUMBER.
122        MSAVEVALUE 1,1,P1,K22       NETWORK NODE NUMBER.
```

```
123        ASSIGN      1+,K1              NEXT COL. OF MX1 TO BE USED.              788
124        SAVEVALUE   90,K2              RANGE OF MATRIX ROW NOS.                  789
125        TRANSFER    ,CBFC1                                                       790
126 FLYCB  ASSIGN      8,K4               LOWEST MATRIX ROW NUMBER.                 791
127        MSAVEVALUE  1,1,P1,K23         NETWORK NODE NUMBER.                      792
128        ASSIGN      1+,K1              NEXT COL. OF MX1 TO BE USED.              793
129        SAVEVALUE   90,K3              RANGE OF MATRIX ROW NOS.                  794
130 CBFC1  TRANSFER    SBR,RNGEN,10                                                 795
131        ASSIGN      8+,X90             MATRIX ROW NUMBER.                        796
132        SAVEVALUE   24,XH71            P.T.O. HP. ON P-T FORAGE HARVESTER        797
133        SAVEVALUE   49,X24             A NECESSARY DUMMY VALUE.                  798
134        TRANSFER    SBR,DTRCT,15       DIESEL TRACTOR ON FRG. HRVSTR.            799
135        MSAVEVALUE  1,1,38,V100        P.A. F.C. OF TRACTOR ON HRVSTR.           800
136        TRANSFER    ,DCUT1                                                       801
137 SPFCB  ASSIGN      8,K11              LOWEST MATRIX ROW NUMBER.                 802
138        MSAVEVALUE  1,1,P1,K24         NETWORK NODE NUMBER.                      803
139        ASSIGN      1+,K1              NEXT COL. OF MX1 TO BE USED.              804
140        SAVEVALUE   90,K1              RANGE OF MATRIX ROW NOS.                  805
141        TRANSFER    SBR,RNGEN,10                                                 806
142        ASSIGN      8+,X90             MATRIX ROW NUMBER.                        807
143        SAVEVALUE   24,MH7(*8,3)       DIESEL PTO. HP.                           808
144 DCUT1  SAVEVALUE   13+,MH7(*8,1)      INITIAL COST OF 1 UNIT IN $               809
145        SAVEVALUE   20,MH7(*8,4)       PER ANNUM FIXED COST.                     810
146        SAVEVALUE   22+,MH7(*8,5)      REPAIR COST IN CENTS/HOUR.                811
147        SAVEVALUE   6+,V100            UPDATE TOTAL P.A. MCH. & EQMT. COST       812
148        SAVEVALUE   25,MH7(*8,2)       WIDTH OF CUT IN FEET X100.                813
149        SAVEVALUE   29,XH11,H          POWER REQMT. FOR F.M.SILAGE               814
150        ASSIGN      16,K5              MATRIX ROW NUMBER.                        815
151        SAVEVALUE   47,XH16            YIELD OF FIRST CUT                        816
152        LOGIC R     11                                                           817
153 AAAP4  TRANSFER    SBR,RATE1,15       FIND WIDTH-DEPENDENT RATE                 818
154        SAVEVALUE   49,X28             TEMP. STRG. OF RATE                       819
155        SAVEVALUE   27,XH55            FIELD EFFICIENCY FRG.HRVSTR. %            820
```

```
156 AAAP5 TRANSFER    SBR,RATE2,15     FIND POWER-DEPENDENT RATE
157       TEST G      X28,X49,AAAP6
158       SAVEVALUE   28,X49           SMALLER AC./HR. X1000 TAKEN AS LIMTG.
159 AAAP6 GATE LR     11,SLGW3         IF 2ND OR LATER CUT, GO TO SLGW3
160       TRANSFER    ,DCLT2           DETERMINE TYPE OF TRANSPORT UNIT.
161 DRAT2 SAVEVALUE   35,K8            RHO SUB DM APPROXIMATION--A.E.'57.
162       TRANSFER    PICK,163,164
163       TRANSFER    ,HMSLG           HIGH MOISTURE SILAGE - PIT OR BUNK
164       TRANSFER    ,DEHYD           DEHYDRATED FORAGE.
165 HMSLG SAVEVALUE   38,K300          3 MIN./LD. UNLOAD TIME
166       MSAVEVALUE  1,1,P1,K42       NETWORK NODE NUMBER.
167       ASSIGN      1+,K1            NEXT COL. OF MX1 TO BE USED.
168       LOGIC R     2                INDICATES HIGH MOISTURE SILAGE
169       TEST GE     X38,X33,DDD
170       SAVEVALUE   38,X33           MAX. UNLOADING RATE  MIN./LD. X100
  * FIND PACKING RATE.
171 DDD   TEST G      XH10,K70,EEE
172       TRANSFER    PICK,173,174     RATES GIVEN AS FOR 20% D.M. GRASS
173       TRANSFER    ,ONEA            ONE TRACTOR-&-OPERATOR UNIT
174       TRANSFER    ,TWOA            TWO TRACTOR-&-OPERATOR UNITS
175 ONEA  SAVEVALUE   50,K1            ONE UNIT
176       MSAVEVALUE  1,1,P1,K82       NETWORK NODE NUMBER.
177       ASSIGN      1+,K1            NEXT COL. OF MX1 TO BE USED.
178       SAVEVALUE   39,K1500         PACKING RATE MIN./LD. X100
179       TRANSFER    ,SLGW2
180 TWOA  SAVEVALUE   50,K2            TWO UNITS
181       MSAVEVALUE  1,1,P1,K83       NETWORK NODE NUMBER.
182       ASSIGN      1+,K1            NEXT COL. OF MX1 TO BE USED.
183       SAVEVALUE   39,K750          PACKING RATE MIN./LD. X100
184       TRANSFER    ,SLGW2
185 EEE   TRANSFER    PICK,186,187     RATES GIVEN AS FOR 30% D.M. GRASS
186       TRANSFER    ,ONEB
187       TRANSFER    ,TWOB
```

```
188 ONEB   SAVEVALUE  50,K1                  ONE UNIT
189        MSAVEVALUE 1,1,P1,K82             NETWORK NODE NUMBER.
190        ASSIGN     1+,K1                  NEXT COL. OF MX1 TO BE USED.
191        SAVEVALUE  39,K2500               PACKING RATE MIN./LD. X100
192        TRANSFER   ,SLGW2
193 TWOB   SAVEVALUE  50,K2                  TWO UNITS
194        MSAVEVALUE 1,1,P1,K83             NETWORK NODE NUMBER.
195        ASSIGN     1+,K1                  NEXT COL. OF MX1 TO BE USED.
196        SAVEVALUE  39,K1250               PACKING RATE MIN./LD. X100
    25     FVARIABLE  X34*(1000+XH38)/1000+1/2
    26     FVARIABLE  X38*(1000+XH38)/1000+1/2
    27     FVARIABLE  XH17*10*(1/XH83+1/XH84)*6000+1/2
    28     FVARIABLE  X32*(1000+XH39)/1000+1/2
197 SLGW2  SAVEVALUE  34,V25                 STD. MANOEUVERING TIME MIN./LOAD X100
198        SAVEVALUE  38,V26                 STD. UNLOADING TIME MIN./LOAD X100
199        SAVEVALUE  35,V27                 TRAVELLING TIME MIN./LOAD X100
   * NOTE: ONLY IF A %P.A. IS INCLUDED IN THE ORIGINAL XH83 AND XH84.
200        SAVEVALUE  32,V28                 STD. HITCH-UNHITCH TIME MIN./LOADX100
201        ASSIGN     17,K32                 BAD DAYS FN. NO.
202        ASSIGN     18,K33                 GOOD DAYS FN. NO.
203        SAVEVALUE  79,K680                PROBABILITY OF A GOOD DAY X1000
204        SAVEVALUE  89,K3                  MAX. NO. OF TRANSPORTING UNITS
205        ADVANCE    173,2                  JUNE 22 +/- 2 DAYS
206        TRANSFER   SBR,SDCUT,14
207        SAVEVALUE  51,XH81                NO. OF TRANSPORTING UNITS -FIRST CUT
208        GATE LS    2,PCKG1                IF PACKING UNITS USED, GO TO PCKG1
209        SAVEVALUE  50,K0
210 PCKG1  SAVEVALUE  80,X51,H               NO. OF MEN=NO.OF TRANSPORTING DRIVERS
211        SAVEVALUE  80+,K1,H               PLUS ONE HARVESTER OPERATOR
212        SAVEVALUE  80+,X50,H              PLUS PACKING-UNIT DRIVERS.
213        SAVEVALUE  90,XH80,H              FIRST CUT.
214        MSAVEVALUE 1,1,26,X86             ACRES NOT HARVESTED(1).
215        MSAVEVALUE 1,1,30,X53             STD. MIN./MAN DURING HARVESTING(1).
```

```
216        MSAVEVALUE 1,1,28,X85        DAYS TO HARVEST (1).
217        GATE LS    20,HTRN1          IF HIRED TRNS. UNITS, GO TO HTRN1.
     29    FVARIABLE  XH80*X53*XH20/60+1/2
218        SAVEVALUE  9+,V29            UPDATE PER ANNUM LABOUR COST
219        TRANSFER   ,CUT2
220 HTRN1  SAVEVALUE  80-,X50           CUSTOM CHARGES INCLUDE DRIVER WAGES.
221        SAVEVALUE  81-,X51           CUSTOM CHARGES INCLUDE DRIVER WAGES.
222        SAVEVALUE  9+,V29            UPDATE PER ANNUM LABOUR COST
223 CUT2   SAVEVALUE  47,XH18           YIELD OF SECOND CUT
224        LOGIC S    11                SECOND CUT INDICATED.
225        TRANSFER   ,AAAP4
226 SLOW3  ASSIGN     17,K34            BAD DAYS FN. NO.
227        ASSIGN     18,K35            GOOD DAYS FN. NO.
228        SAVEVALUE  79,K676           PROBABILITY OF A GOOD DAY X1000
   * NOTE : ENSURE THAT THE CLOCK TIME AT END OF FIRST CUT IS NOT >=229.
229        SAVEVALUE  100,K229,H
230        SAVEVALUE  100-,M1,H         CLOCK TIME
231        ADVANCE    XH100,2           AUG. 17 +/- 2 DAYS
232        TRANSFER   SBR,SDCUT,14
233        SAVEVALUE  54,XH81
234        SAVEVALUE  80,X54,H
235        SAVEVALUE  80+,K1,H
236        SAVEVALUE  80+,X50,H
237        SAVEVALUE  91,XH80,H         SECOND CUT.
238        MSAVEVALUE 1,1,27,X86        ACRES NOT HARVESTED(2).
239        MSAVEVALUE 1,1,31,X53        STD. MIN./MAN DURING HARVESTING(2).
240        MSAVEVALUE 1,1,29,X85        DAYS TO HARVEST (2).
241        GATE LS    20,HTRN2          IF HIRED TRNS. UNITS, GO TO HTRN2.
242        SAVEVALUE  9+,V29            UPDATE PER ANNUM LABOUR COST
243        TRANSFER   ,TTEST
244 HTRN2  SAVEVALUE  80-,X50           CUSTOM CHARGES INCLUDE DRIVER WAGES.
245        SAVEVALUE  81-,X51           CUSTOM CHARGES INCLUDE DRIVER WAGES.
246        SAVEVALUE  9+,V29            UPDATE PER ANNUM LABOUR COST
```

```
    *       FIND THE LARGEST NUMBER OF TRANSPORTING UNITS REQUIRED.
247 TTEST  TEST LE    XH81,X51,FHOPC
248        SAVEVALUE  81,X51,H            IF X51 IS THE LARGER NO. OF UNITS.
    * FIND FORAGE HARVESTING OPERATING COST ASSUMING NO OPERATION DURING DE
    * LAYS THAT OCCUR DUE TO WAITING FOR A TRANSPORT UNIT.
249 FHOPC  SAVEVALUE  29,XH66             AVG. DIESEL CONS. GAL/PTO.HP-HR X1000
250        SAVEVALUE  30,XH23             COST OF DIESEL CENTS/GAL. X10
    * NOTE: IN CALCULATING POWER UNIT OPERATING COST WE ASSUMED COST OF OIL
    * LUBRICANTS, ETC. TO BE 15% OF FUEL COST(A.S.A.E. YEARBOOK - 1969)
    32     FVARIABLE  X55*X24*X29*X30*115/(60000*1000)+X55*X22/60+1/2
251        SAVEVALUE  7+,V32              UPDATE TOTAL MACH. OPN. COST
252        GATE LR    20,PTRNS            IF OWN TRNS. UNITS, GO TO PTRNS.
    * FIND CUSTOM CHARGES FOR THE TRANSPORT POWER UNITS.
253        SAVEVALUE  19,XH81             NO. OF TRANSPORTING UNITS.
254        GATE LR    3,HTRNS             IF TRUCK POWER, GO TO HTRNS.
    * FOR TRACTOR POWER,
255        SAVEVALUE  20,XH40             CENTS PER HOUR CHARGED.
256        TRANSFER   ,HTRN4
    * FOR TRUCK POWER,
257 HTRNS  SAVEVALUE  20,XH41             CENTS PER HOUR CHARGED.
    21     FVARIABLE  (X51*MX1(1,28)+X54*MX1(1,29))*X20*X31
258 HTRN4  MSAVEVALUE 1,1,43,V21
259        GATE LS    3,WGN3              IF WAGONS USED, GO TO WGN3.
260        TRANSFER   ,CCC1
    * FIND PER ANNUM FIXED COST OF TRANSPORT UNITS.
261 PTRNS  SAVEVALUE  19,XH81             NO. OF TRANSPORTING UNITS.
262        GATE LR    3,TPAFC             IF TRUCK POWER, GO TO TPAFC.
263 WGN3   SAVEVALUE  19+,K1              ADD THE UNIT FILLING.
264        SAVEVALUE  21,XH34             AMORT. RATE FOR WAGONS.
265        SAVEVALUE  13+,V8              UPDATE TOTAL OUTLAY FOR MACHINERY.
266        SAVEVALUE  22,MX2(1,15)        REPAIR RATE IN % OF LIST /100 HOURS.
    101    FVARIABLE  X22*V8/100
267        SAVEVALUE  111,V101            REPAIR RATE IN CENTS/HOUR.
```

```
268       SAVEVALUE  14+,V9            UPDATE P.A.F.C. OF TRNSPRT. UNITS
269       TRANSFER   ,FHTCC
270 TFAFC SAVEVALUE  21,XH34           AMORT. RATE  %X10.
271       SAVEVALUE  13+,V8            UPDATE TOTAL OUTLAY FOR MACHINERY.
272       SAVEVALUE  22,MX2(3,15)      REPAIR RATE IN % OF LIST /100 HOURS.
273       SAVEVALUE  111,V101          REPAIR RATE IN CENTS/HOUR.
274       MSAVEVALUE 1+,1,42,V9        UPDATE P.A.F.C. OF TRNSPRT. UNITS.
   * FIND OPERATING COSTS OF TRANSPORT UNITS.
275 FHTOC GATE LR    3,CCC             IF NOT TRACTOR DRAWN, GO TO  CCC
    33    FVARIABLE  X52*(X32+X34+X35+X33)/1000+1/2
276       MSAVEVALUE 1,1,37,V33        TOTAL OPERATING MIN. OF TRANS. UNITS.
277       GATE LS    20,PCKFC
    34    FVARIABLE  XH76*XH65*XH22*V33*115/(60000*1000)+1/2
278       SAVEVALUE  7+,V34            UPDATE TOTAL MCH. OPERATING COST
   * FIND P.A. F.C. OF TRACTORS ON TRANSPORT UNITS.
279       SAVEVALUE  49,XH76           P.T.O. HP. ON TRANSPORT UNITS.
280       SAVEVALUE  19,XH81           NO. OF TRACTORS.
281       TRANSFER   SBR,CTRCT,15
282       SAVEVALUE  13-,X20           DO NOT UPDATE OUTLAY YET.
283       SAVEVALUE  36,X20
284       SAVEVALUE  13+,V8            UPDATE TOTAL OUTLAY FOR MACHINERY
285       SAVEVALUE  22,MX2(5,15)      REPAIR RATE IN % OF LIST /100 HOURS.
286       SAVEVALUE  111+,V101         REPAIR RATE IN CENTS/HOUR.
287       SAVEVALUE  36,V100           P.A. F.C. OF ONE UNIT.
288       MSAVEVALUE 1+,1,42,V8        P.A. F.C. OF TRCTR(S) OR TRUCK(S)
289       TRANSFER   ,PCKFC
    35    FVARIABLE  ((X34+X32)/6000+XH17*10/XH64)*XH84/XH69+1/2
    36    FVARIABLE  (V35+(X33/6000+XH17*10/XH83)*XH87/XH68)*X52*XH22/100
290 CCC   SAVEVALUE  7+,V36            UPDATE TOTAL MCH. OPN. COST
    81    FVARIABLE  X52*(X32+X34+X33)/100+1/2
    82    FVARIABLE  V81+X52*XH17*10*60*(1/XH84+1/XH83)+1/2
291 CCC1  MSAVEVALUE 1,1,37,V82        TOTAL OPERATING MIN. OF TRANS. UNITS.
   * FIND REPAIR COST OF TRANSPORT UNITS.
```

```
     102   FVARIABLE  MX1(1,37)*X111/(XH81*60)+1/2
292 PCKFC  SAVEVALUE  7+,V102           UPDATE TOTAL MCH. OPERATING COSTS.
293        GATE LR    2,DHYFC           IF DEHYDRATION, GO TO DHYFC.
   * FIND OPERATING MINUTES OF PACKING UNITS.
     37    FVARIABLE  X52*X39*(1000+XH38)/1000000+1/2
294        MSAVEVALUE 1+,1,36,V37       TOTAL MIN. PACKING.
295        GATE LS    20,HSILO          IF HIRED TRNS. UNITS, GO TO HSILO.
   * FIND PER ANNUM OPERATING COST ASSUMING THAT UNITS ARE ONLY RUNNING
   * WHEN PACKING OPERATION IS UNDERWAY.
     38    FVARIABLE  V37*XH76*XH65*XH22*115/(10000*50000)+1/2
296        SAVEVALUE  7+,V38            UPDATE TOTAL MCH. OPERATING COSTS.
   * ADD P.A. FIXED AND OPN. COST OF PACKING TRACTORS.
297        SAVEVALUE  19,X50            NUMBER OF PACKING TRACTORS.
298        SAVEVALUE  49,XH76           PTO H.P. REQUIRED FOR PACKING TRCTRS.
299        TRANSFER   SBR,GTRCT.15
300        SAVEVALUE  13-,X20           DO NOT UPDATE OUTLAY YET.
301        SAVEVALUE  36,X20
302        SAVEVALUE  13+,V8
303        SAVEVALUE  22,MX2(5,15)      REPAIR RATE IN % OF LIST/100 HOURS.
304        SAVEVALUE  111,V101          REPAIR RATE IN CENTS/HOUR.
305        SAVEVALUE  36,V100           P.A.F.C. OF ONE UNIT.
306        MSAVEVALUE 1,1,41,V8         P.A.F.C. OF TRCTRS ON PCKNG. UNITS.
   * ADD REPAIR COSTS TO OPERATING COSTS.
     103   FVARIABLE  MX1(1,36)*X111/(X19*60)+1/2
307        SAVEVALUE  7+,V103           UPDATE TOTAL MCH. OPERATING COSTS.
   * HORIZONTAL SILOS -- PIT OR TRENCH AND BUNKER TYPES.
308 HSILO  TRANSFER   PICK,309,311
309        TRANSFER   ,TTT              HORIZ. SILO - SELF-FEEDER
310        TRANSFER   ,UUU              HORIZ. SILO -FRNT-END LOADER + ATTCH.
311        TRANSFER   ,VVV              HORIZ. SILO - UNLOADERS(TRACTOR-MTD)
312 TTT    SAVEVALUE  104,K1            LIST REFERENCE NUMBERS 1 TO 7
313        MSAVEVALUE 1,1,P1,K111       NETWORK NODE NUMBER.
314        ASSIGN     1+,K1             NEXT COL. OF MX1 TO BE USED.
```

```
315      SAVEVALUE  90,K6
316      TRANSFER   SBR,RNGEN,10
317      SAVEVALUE  104+,X90          LIST REFERENCE NO. CHOSEN(HORIZ.SILO)
318      TEST GE    X50,K2,WWW
319      SAVEVALUE  104,K2            IF 2 TRACTORS PACKING IN A 12' WIDE
   *     SILO, INTERFERENCE IS LIKELY.
320      SAVEVALUE  90,K5
321      TRANSFER   SBR,RNGEN,10
322      SAVEVALUE  104+,X90          LIST REFERENCE NO. CHOSEN(HORIZ.SILO)
323 WWW  ASSIGN     11,K1
324      TRANSFER   ,XXX
325 UUU  ASSIGN     11,K2             INDICATES FRNT.-END LOADER ATTACHMT.
326      MSAVEVALUE 1,1,P1,K105       NETWORK NODE NUMBER.
327      ASSIGN     1+,K1             NEXT COL. OF MX1 TO BE USED.
328      SAVEVALUE  104,K1
329      SAVEVALUE  90,K17            LIST REF. NOS. 1 TO 18
330      TRANSFER   SBR,RNGEN,10
331      SAVEVALUE  104+,X90          LIST REFERENCE NO. CHOSEN(HORIZ.SILO)
332      ASSIGN     8,K25
333      SAVEVALUE  90,K1
334      TRANSFER   SBR,RNGEN,10
335      ASSIGN     8+,X90            FRNT.-END LOADER CHOSEN.
336      TRANSFER   ,W W W1
337 VVV  SAVEVALUE  90,K3
338      MSAVEVALUE 1,1,P1,K8S        NETWORK NODE NUMBER.
339      ASSIGN     1+,K1             NEXT COL. OF MX1 TO BE USED.
340      TRANSFER   SBR,RNGEN,10
341      SAVEVALUE  90+,K13           MCH.NO. IN MATRIX MH7 .
342      ASSIGN     8,X90
343      SAVEVALUE  104,K1
344      SAVEVALUE  90,MH7(*8,3)      LIST REF. NO. 1 TO X90+1 POSSIBLE.
345      TRANSFER   SBR,RNGEN,10
346      SAVEVALUE  104+,X90          LIST REFERENCE NO. CHOSEN(HORIZ.SILO)
```

```
347 WWW1   SAVEVALUE  13+,MH7(*8,1)     INITIAL COST IN $                        1052
348        SAVEVALUE  20,MH7(*8,4)      PER ANNUM FIXED COST.                    1053
349        SAVEVALUE  6+,V100           UPDATE P.A. MCH. & EQUIPMT. COST.        1054
  * SINCE PACKING OPERATION REQUIRES SMALL GASOLINE TRACTORS, THE               1055
  * P.A.F.C. ASSOCIATED WITH THIS TRACTOR HAS ALREADY BEEN ACCOUNTED FOR.      1056
  * FIND STORAGE REQUIREMENTS - HORIZONTAL SILOS                                1057
350 XXX    SAVEVALUE  21,K50                                                     1058
351        SAVEVALUE  22,K12            PER ANNUM REPAIR RATE %X10.              1059
   39      FVARIABLE  X57*2000000/(FN30*35*(100-XH10)*XH37)+1/2                  1060
352        SAVEVALUE  85,V39,H          SILO LENGTH REQUIRED FT. X10             1061
   40      FVARIABLE  FN28*XH85/1000+1/2                                         1062
353        SAVEVALUE  16+,V40           UPDATE OUTLAY FOR STORAGE FACILITIES     1063
   41      FVARIABLE  FN28*XH85*(X21/10+XH30+XH31/10+X22/10)/1000                1064
354        SAVEVALUE  8+,V41            UPDATE TOTAL P.A. STORAGE COST           1065
   42      FVARIABLE  XH85*FN29/10+1/2                                           1066
355        SAVEVALUE  8+,V42            UPDATE TOTAL P.A. STORAGE COST           1067
  * TAKEN FROM N.R.C. TABLES AND CONVERTED FORM 30% D.M. BASIS TO 100%         1068
  * D.M. BASIS .                                                               1069
356        SAVEVALUE  118,K113          % DCP X10  D.M. BASIS                    1070
357        SAVEVALUE  119,K1200         KCAL./LB. OF DRY MATTER                  1071
   43      FVARIABLE  (X57-X120)*FN11*(X118*X1+X119*X2*2)/(1000*1000)+1/2        1072
358        SAVEVALUE  5+,V43            UPDATE TOTAL STORAGE LOSSES.             1073
  * FIND TOTAL TONS OF WET MATERIAL TO UNLOAD.                                 1074
   44      FVARIABLE  X57*(100-FN11)/(100-XH10)+1/2                              1075
359        SAVEVALUE  43,V44            TOTAL T. W.M. TO UNLOAD X10              1076
360        TEST E     P11,K1,YYY                                                 1077
  * FOR SELF-FEEDER, RICHEY CLAIMS ONE MIGHT EXPECT 50% LOSS. IF WE           1078
  * ASSUME THAT WITH GOOD MANAGEMENT THIS CAN BE REDUCED TO 25%,THEN           1079
361        SAVEVALUE  42,K25                                                     1080
362        SAVEVALUE  90,K25                                                     1081
363        TRANSFER   SBR,RNGEN,10                                               1082
364        SAVEVALUE  42+,X90           % EXTRA LOSS DUE TO TRAMPLING,ETC.       1083
   45      FVARIABLE  X42*(X43*(100-XH10)/100-X120)/100+1/2                      1084
```

```
   46     FVARIABLE  V45*(X118*X1+X119*X2*2)/10000+1/2
365       SAVEVALUE  10+,V46           UPDATE TOTAL P.A. DISTRIBUTION COSTS
  * FIND PER ANNUM COST OF SELF-FEEDER -- HORIZONTAL SILO.
366       SAVEVALUE  20,K50
  *       WIDTH OF HORIZONTAL SILO - A.D.A. AG. ENG. EXT. $36.50  1965
367       SAVEVALUE  90,K25            ARBITRARILY SET AT $50-75 PER 20'
368       TRANSFER   SBR,RNGEN,10
369       SAVEVALUE  20+,X90           $I.C. MATERIALS FOR SELF-FEEDING GATE
  *                                    FOR 20' WIDTH.
370       SAVEVALUE  21,XH33
371       SAVEVALUE  22,K24            TOTAL REPAIR RATE %X10 -- ARBITRARILY
  *                                    TWICE THAT OF THE SILO.
   47     FVARIABLE  X20*FN31*15/2000+1/2
   48     FVARIABLE  V47*(X21/10+XH30+XH31/10+X22/10)+1/2
372       SAVEVALUE  10+,V48           UPDATE TOTAL P.A. DISTRIBUTION COSTS
  * FIND PER ANNUM LABOUR COST OF MOVING SELF-FEEDER.
   49     FVARIABLE  XH20*FN31*XH85*(1000+XH39)/(20*1000*60)+1/2
  * TIME DATA FOR MOVING OF SELF-FEEDER IS ASSUMED AS 10 MIN. FOR
  * MOVING A 20 FT. SECTION.
373       SAVEVALUE  10+,V49           UPDATE TOTAL P.A. DISTRIBUTION COSTS.
374       TRANSFER   ,ZZZ2
375 YYY   TEST E     P11,K2,ZZZ
  * FOR TRACTOR-MOUNTED MANURE LOADER, WE 'ASSUME' NO APPRECIABLE LOSS OF
  * DRY MATTER DUE TO MECHANICAL HANDLING.
376       SAVEVALUE  86,K70,H          EQUIPMT. COSTS ALREADY CALCULATED.
377       SAVEVALUE  90,K10            RANGE OF 7-8 T.W.M./HR. CAPACITY.
378       TRANSFER   SBR,RNGEN,10
379       SAVEVALUE  86+,X90           H. SILO UNLOADING RATE T. W.M./HR.X10
380       SAVEVALUE  49,XH86           UNLOADING RATE IN T. W.M./HR. X10 .
381       TRANSFER   ,ZZZ1
382 ZZZ   SAVEVALUE  87,K120,H
383       SAVEVALUE  90,K30            RANGE OF 12-15 T W.M. /HR.
384       TRANSFER   SBR,RNGEN,10
```

```
385          SAVEVALUE  87+,X90            MECH. H.SILO UNLDR. RATE T.WM./HP.X10
386          SAVEVALUE  49,XH87            UNLOADING RATE IN T. W.M./HR. X10 .
387          TRANSFER   ,ZZZ1
   * FIND TIME (MINUTES) SPENT BY UNLOADING UNIT.
    50       FVARIABLE  60*X43*(1000+XH38)/(1000*X49)+1/2
388 ZZZ1     MSAVEVALUE 1+,1,36,V50        TIME FOR UNLOADING.
   * IF CUSTOM CHARGES MADE IN THE HARVESTING OPERATION, THE SAME RATES
   * ON A TOTAL HOURS BASIS ARE USED HERE.
389          GATE LS    20,ZZZ1A
   * FIND P.A. OPERATING COST OF MECHANICALLY UNLOADING THE SILO.
    51       FVARIABLE  XH76*XH65*XH22*V50*115/(10000*6000)+V50*X111/60+1/2
390          SAVEVALUE  10+,V51            UPDATE TOTAL P.A. DISTRIBUTION COSTS.
   * FIND P.A. LABOUR COST ( NO DELAYS ACCOUNTED FOR).
    52       FVARIABLE  XH20*V50/60+1/2
391          SAVEVALUE  10+,V52            UPDATE TOTAL P.A. DISTRIBUTION COSTS.
392          TRANSFER   ,ZZZ1B
393 ZZZ1A    SAVEVALUE  20,XH40
394          SAVEVALUE  19,V50
    22       FVARIABLE  X19*X20/60+1/2
395          SAVEVALUE  10+,V22            UPDATE TOTAL P.A. DISTRIBUTION COST.
396 ZZZ1B    SAVEVALUE  42,K0              NO LOSSES DUE TO TRAMPLING.
   * FIND TOTAL TONS OF DRY MATTER FED.
    53       FVARIABLE  (100-X42)*X43*(100-XH10)/10000+1/2
397 ZZZ2     SAVEVALUE  43,V53             TOTAL TONS D.M. FED X10
398          TRANSFER   ,SUMRY
   * DEHYDRATION ( TO 10% MOISTURE CONTENT WET BASIS)
399 DEHYD    SAVEVALUE  38,X33             MAX. UNLDG. RATE MIN./LD. X100
400          MSAVEVALUE 1,1,P1,K41         NETWORK NODE NUMBER.
401          ASSIGN     1+,K1              NEXT COL. OF MX1 TO BE USED.
402          LOGIC S    2                  INDICATES DEHYDRATION.
    54       FVARIABLE  X31*10*(XH10-10)*(100/XH46)/3+1/2
403          SAVEVALUE  39,V54             MAX. DEHYD. RATE MIN./LOAD X100
    55       FVARIABLE  X31*(100-XH10)*6000/(X35*2375)+1/2
```

```
404          TEST C      V55,X39,SSS          IF DEHYD. RATE LIMITING, GO TO SSS
405          SAVEVALUE   39,V55              FEEDER RATE LIMITING MIN./LOAD X100
406 SSS      TRANSFER    ,SLGW2
   * FIND PER ANNUM FIXED COSTS CF DEHYDRATOR UNIT.
407 DHYFC    SAVEVALUE   13+,K84320           TOTAL I.C. LESS WEATHER PROTECTION.
   * THIS COST FIGURE INCLUDES COST OF ELECTRIC MOTORS.
408          SAVEVALUE   20,K84320
409          SAVEVALUE   21,XH33              AS FOR P-T UNITS.
410          SAVEVALUE   22,K843              ASSUMED EQUIV.TO STATIONARY POWR UNIT
   *                                          I.E. 120% OVER 12000 HOURS.
411          SAVEVALUE   23,K0                HOUSING COST TO BE CALC. LATER.
412          SAVEVALUE   6+,V10               UPDATE TOTAL P.A. MCH. & EQMT. COST.
   * FIND OPERATING COSTS OF ELECTRIC MOTORS ON DEHYDRATOR UNIT.
    56       FVARIABLE   X52*X39*(1000+XH38)*122/(60000*1000)+1/2
    57       FVARIABLE   V56*7452*XH21/1000000+1/2
413          SAVEVALUE   7+,V57               UPDATE TOTAL P.A. MCH. OPERATING COST
   * FIND OPERATING COST OF FURNACE CN DEHYDRATOR UNIT.
    58       FVARIABLE   X52*X31*(XH10-10)*180*175*(100/XH46)/180000+1/2
414          SAVEVALUE   7+,V58               UPDATE TOTAL P.A. MCH. OPN. COST
   * SINCE LABOUR ALREADY CALCULATED FOR THIS TASK,
415          SAVEVALUE   10,K10,H             NEW %M.C.(W.B.)
   * FIND INITIAL COST AND P.A. F.C. CF POLE-FRAME, TRUSS RAFTER, WALL-
   * LESS WEATHER PROTECTION FOR DEHYDRATOR.  APPROXIMATELY 1500 FT.**2  .
416          SAVEVALUE   19,K1500             APPROX. AREA IN SQ.FT.
417          SAVEVALUE   20,K95               MINIMUM CENTS/SQ.FT.
418          SAVEVALUE   90,K45               COST RANGES FROM $.95 TO $1.40/SQ.FT.
419          TRANSFER    SBR,RNGEN,10
420          SAVEVALUE   20+,X90              CENTS PER SQ.FT.
    83       FVARIABLE   X19*X20/100+1/2
421          SAVEVALUE   13+,V83              UPDATE TOTAL OUTLAY FOR MACHINERY.
422          SAVEVALUE   20,V83               1 I.C.
423          SAVEVALUE   21,K50               5% AMORTIZATION.
424          SAVEVALUE   22,1                 1% PER ANNUM REPAIRS.
```

```
      84    FVARIABLE  X20*(X21/10+XH30+1+X22)+1/2                                  1184
425         SAVEVALUE  64,V84              UPDATE TOTAL P.A. MCH. & EGMT. COST.    1185
     * I.E. 8% INTEREST, 5% AMORTIZATION, 1% INSURANCE, 1% REPAIRS.                  1186
     * FIND STORAGE FOR DEHYDRATED ALFALFA HAY.                                      1187
     * AN AVERAGE BUILDING OF 32' WIDE AND 16' SIDE-WALL ON A CONCRETE PAD.          1188
     * POLE FRAME CONSTRUCTION WITH TRUSS RAFTERS , TOTALLY ENCLOSED.  IF            1189
     * FILLED TO A 14' DEPTH, EFFECTIVE ENDWALL AREA IS 448 SQ.FT. , AND             1190
     * CAPACITY IS 2.24 TONS(W.M.) PER LINEAR FOOT AT 10 P.C.F.                      1191
426         SAVEVALUE  20,K125                                                      1192
427         SAVEVALUE  90,K25              COST OF $1.25 - $1.50 PER SQ.FT.         1193
428         TRANSFER   SBR,RNGEN,10                                                 1194
429         SAVEVALUE  20+,X90             COST PER SQ.FT. OF BUILDING.             1195
430         SAVEVALUE  20+,K60             ADD COST OF CONCRETE FLOOR.              1196
      85    FVARIABLE  X57*10000/((100-XH10)*224)+1/2                               1197
431         SAVEVALUE  85,V85,H            LINEAR FEET X10 REQUIRED.                1198
432         SAVEVALUE  19,K32              BUILDING WIDTH.                          1199
      86    FVARIABLE  X19*XH85*X20/1000+1/2                                        1200
433         SAVEVALUE  20,V86              $I.C. OF BUILDING.                       1201
434         SAVEVALUE  16+,X20             UPDATE TOTAL OUTLAY FOR STORAGE.         1202
435         SAVEVALUE  21,K50              AMORT. RATE %X10.                        1203
436         SAVEVALUE  22,K2               F.A. REPAIR RATE %.                      1204
437         SAVEVALUE  84+,V84             UPDATE TOTAL P.A. STORAGE COST.          1205
     * FOR COMPARISON PURPOSES, LET US SAY THAT THE DEHYDRATOR IS CLOSE TO           1206
     * THE STORAGE SITE AND A FLIGHT-&-CHAIN CONVEYOR THE LENGTH OF THE              1207
     * STORAGE FACILITY PLUS 10 FT. IS ADEQUATE FOR STORING THE FORAGE.  THE         1208
     * ANGLE OF REPOSE IS 60 DEGREES(NEUBAUER AND WALKER); MAXIMUM F-&-C             1209
     * CONVEYOR SPEED OF 125 F.P.M.; FLIGHT DIMENSIONS ARE 3''X21''X14''.            1210
     * EVEN AT A MAXIMUM FLIGHT VOLUME OF LEVEL FULL, THE F-&-C CONVEYOR             1211
     * CAN MORE THAN ADEQUATELY HANDLE THE DEHYDRATED MATERIAL AT MAXIMUM            1212
     * DEHYDRATOR OUTPUT.                                                            1213
438         SAVEVALUE  85+,K10,H           LENGTH OF F-&-C CONVEYOR .               1214
439         SAVEVALUE  20,K100             $X10 PER FOOT OF CONVEYOR EXTENSION.     1215
440         SAVEVALUE  19,XH85             LINEAR FEET X10.                         1216
```

```
441        SAVEVALUE  13+,V83          UPDATE TOTAL OUTLAY FOR MACHINERY.      1217
442        SAVEVALUE  20,V83           DOLLARS INITIAL COST.                   1218
443        SAVEVALUE  21,XH33          AMORT. RATE  %X10.                      1219
444        SAVEVALUE  22,K25           T. REPAIR RATE (AS FOR 1. SILO UNLDR)   1220
445        SAVEVALUE  23,XH32          MACHINERY HOUSING RATE %.               1221
446        SAVEVALUE  6+,V10           UPDATE TOTAL P.A. MCH. & EQMT. COST.    1222
    88     FVARIABLE  2*XH64*XH85*3*5/10+1/2                                   1223
   * THE  '55' FIGURE WAS TAKEN FROM FN12 AT 40% M.C.(W.B.)                    1224
    89     FVARIABLE  (X31*XH10*100000/(XH49*X39))*(XH85*55/100+15)*10+1/2     1225
    90     FVARIABLE  X41*130/(33000*XH57)+1/2                                 1226
    91     FVARIABLE  X57*(100+XH10)/100+1/2                                   1227
    92     FVARIABLE  X39*X52*(1000+XH38)/60000+1/2                            1228
    93     FVARIABLE  (V92*X101*XH21/1000000)*7452/10000+1/2                   1229
447        SAVEVALUE  41,V88                                                   1230
448        SAVEVALUE  41+,V89                                                  1231
449        SAVEVALUE  41,V90                                                   1232
450        SAVEVALUE  101,X41          EL. HP.X10 REQUIRED OF F-&-C CONVYR.    1233
451        SAVEVALUE  43,V91           TOTAL TONS W.M. X10 STORED.             1234
452        SAVEVALUE  7+,V93           UPDATE MACH. OPN. COST                  1235
   * NOTE: ASSUMING THE F-&-C CONVYR. OPERATES WHEN DEHYDRATOR IS OPRTG.       1236
   * FIND FIXED COST AND PER ANNUM FIXED COST OF ELECTRIC MOTOR.               1237
453        SAVEVALUE  13+,FN2          $I.C. OF 1 UNIT.                        1238
454        SAVEVALUE  20,FN2           $I.C. OF 1 UNIT.                        1239
455        SAVEVALUE  6+,V7            UPDATE TOTAL P.A. MCH. & EQMT. COST.    1240
   * TAKEN FROM N.R.C. TABLES AND CONVERTED FROM 92% D.M. BASIS TO 100%        1241
   * D.M. BASIS, USING THE SAME CONVERSION RATIO ( CP TO DP) AS PRE-BLOOM      1242
   * ALFALFA HAY SINCE THE TON FIGURES APPEAR TO BE QUITE CLOSE.               1243
456        SAVEVALUE  118,K126         %D.P. X10 D.M. BASIS .                  1244
457        SAVEVALUE  119,K1174        KCAL./LB. D.M. BASIS .                  1245
   * ASSUME THAT A FRONT-END LOADER WITH A 21 CU.FT. SCOOP IS USED TO          1246
   * REMOVE THE FORAGE FROM STORAGE AND PLACE IT IN A TRANSPORT UNIT.          1247
458        SAVEVALUE  50+,K1           ADD 1 TO THE NUMBER OF PACKING UNITS.   1248
459        GATE LR    3,DHYTC          IF NO SMALL GASOLINE TRACTOR ALREADY    1249
```

```
    *                                         USED IN TRANSPORT, GO TO DFYTC.
460       SAVEVALUE   49,XH76             PTO H.P.
461       TRANSFER    SBR,GTRCT,15
462       SAVEVALUE   13-,V6              REPAIR RATE IS THE ITEM OF INTEREST.
463       TRANSFER    ,SCOOP
    * FIND INITIAL COST AND PER ANNUM FIXED COST.
464 DFYTC SAVEVALUE   49,XH76             P.T.O. HP.
465       TRANSFER    SBR,GTRCT,15
466       MSAVEVALUE  1+,1,41,V100        P.A. F.C. OF TRCTR. ON LDG. UNIT.
    * FIND INITIAL COST AND PER ANNUM FIXED COST OF FRONT-END LOADER PLUS
    * A 21 CU.FT. SCOOP.
467 SCOOP ASSIGN      8,K25
468       SAVEVALUE   90,K1
469       TRANSFER    SBR,RNGEN,10
470       ASSIGN      8+,X90              FRONT-END LOADER CHOSEN.
471       SAVEVALUE   13+,MH7(*8,1)       UPDATE TOTAL MACHINERY OUTLAY.
472       SAVEVALUE   49,MH7(*8,4)        $ P.A.F.C.
473       SAVEVALUE   6+,V100             UPDATE TOTAL P.A. MCH. & EQMT. COST.
474       SAVEVALUE   111,MH7(*8,5)       REPAIR COST IN CENTS/HOUR.
475       ASSIGN      8,K28               21 CU.FT. BUCKET.
476       SAVEVALUE   13+,MH7(*8,1)       UPDATE TOTAL MACHINERY OUTLAY.
477       SAVEVALUE   49,MH7(*8,4)        $ P.A.F.C.
478       SAVEVALUE   6+,V100             UPDATE TOTAL P.A. MCH. & EQMT. COST.
479       SAVEVALUE   111+,MH7(*8,5)      REPAIR COST IN CENTS/HOUR.
    * SINCE VOLUME OF REGULAR 60'' MANURE BUCKET IS APPROXIMATELY 1/2 CU.
    * YD. AND THE SCOOP HAS A 21 CU.FT. CAPACITY,THE RATIO BECOMES 135/210.
480       SAVEVALUE   90,K10              RANGE
481       TRANSFER    SBR,RNGEN,10
482       SAVEVALUE   90+,K70             7-8 T. W.M./HR. OF SILAGE.
     94   FVARIABLE   X90*(100-XH49)*210*6/(800*135)+1/2
483       SAVEVALUE   49,V94              T. W.M.X10/HR. OF DEHYD. HAY .
484       MSAVEVALUE  1,1,36,V50          OPERATING MIN. OF LOADER.
    * FIND P.A. OPERATING COST OF MECHANICALLY UNLOADING STORE.
```

```
485          GATE LS     20,DHYD1
486          SAVEVALUE   111+,X22           UPDATE TOTAL REPAIR COST IN CENTS/HR.
487          SAVEVALUE   10+,V51
  * FIND P.A. LABOUR COST (NO DELAYS ACCOUNTED FOR).
488          SAVEVALUE   10+,V52
489          TRANSFER    ,DHYD2
490 DHYD1    SAVEVALUE   20,XH40            CENTS PER HOUR CHARGED.
491          SAVEVALUE   20+,X111           INCLUDE REPAIR COST OF LDR. & SCOOP.
492          SAVEVALUE   19,V50
493          SAVEVALUE   10+,V22            UPDATE TOTAL P.A. DISTRIBUTION COST.
494 DHYD2    SAVEVALUE   42,K0              ASSUME NO APPRECIABLE LOSS OF D.M.
  * FIND TOTAL TONS X10 OF DRY MATTER FED.
495          SAVEVALUE   43,V53
496          TRANSFER    ,SUMRY
  *
  *              --  DIRECT-CUT WEATHER SUBROUTINE  --
  *
497 SDCUT    SAVEVALUE   80,K4              CAN RANGE FROM 1 TO 4 - LOW TO HIGH
498          SAVEVALUE   81,K10             MAXIMUM WORKING HOURS PER DAY.
499          SAVEVALUE   86,XH15            ACRES LEFT TO DO.
500          SAVEVALUE   85,K0              INITIALIZE COUNTER.
501          SAVEVALUE   17,K0              TOTAL MATURITY LOSSES ACCUMULATOR.
  * IN AC.-% X1000 , IN TERMS OF 1% DROP IN FORAGE INTAKE PER DAY HARVEST
  * IS DELAYED BEYOND EARLY BLOOM STAGE.
502          SAVEVALUE   118,XH8            CURRENT D.C.F.  %X10 .
503          SAVEVALUE   119,XH9            CURRENT DIGESTIBLE ENERGY KCAL./LB.
  * FIND STANDARD ACRES/HOUR X1000 CAPACITY.
504          TEST LE     X28,K0,CAPY1
  60         FVARIABLE   MH3(*16,X80)*X25*10/(1000+XH38)+1/2
505          SAVEVALUE   28,V60             STD. AC./HR. X1000
  * FIND : LOADING TIME, MANOEUVERING TIME, TRAVEL TIME, HITCH-UNHITCH
  * TIME IN MINUTES/LOAD X100 .
  61         FVARIABLE   X31*(100-XH10)*300000/(X47*X28)+1/2
```

```
506 CAPY1 SAVEVALUE  40,V61           STD. LOADING TIME MIN./LOAD X100
   * DETERMINE WHETHER ANY DELAYS OCCUR FOR FORAGE HARVESTER AT THE MAX.
   * NUMBER OF TRANSPORT UNITS.
507 TRAN1 SAVEVALUE  40,K0            INITIALIZE.
    62    FVARIABLE  ((X35+X34+X38)/X89-(X46+X32))/100+1/2
508       TEST GE    V62,K0,TRAN2     IF NO DELAYS, GO TO TRAN2
   * WHERE DELAYS DO OCCUR, SET NO. OF TRANSPORT UNITS AT THE MAX.
509       SAVEVALUE  40,V62           DELAYS IN MINUTES/LOAD.
510       SAVEVALUE  81,X89,H         NUMBER OF TRANSPORT UNITS.
511       SAVEVALUE  81-,K1,H         NUMBER OF TRANSPORTING UNITS.
512       TRANSFER   ,OCUT3
   * CHECK TO SEE IF ANY DELAYS OCCUR FOR ONE TRANSPORTING UNIT.
    63    FVARIABLE  (X46+X32-(X35+X34+X38))/100+1/2
513 TRAN2 TEST GE    V63,K0,TRAN3
   * WHERE DELAYS DO OCCUR, SET NO. OF TRANSPORTING UNITS TO ONE.
514       SAVEVALUE  81,K1,H          ONE TRANSPORTING UNIT.
515       TRANSFER   ,OCUT3
   * FIND NUMBER OF TRANSPORTING UNITS REQUIRED IF NOT ONE OR THE MAX.
    64    FVARIABLE  (X35+X34+X38)/(X46+X32)+1
516 TRAN3 SAVEVALUE  81,V64,H         NUMBER OF TRANSPORTING UNITS.
517       TRANSFER   ,OCUT3
   * FIND TOTAL LOADS PER DAY AND ACRES PER DAY.
    65    FVARIABLE  X81*60/(X40+(X46+X32)/100)+1/2
518 OCUT3 SAVEVALUE  92,V65           LOADS PER DAY.
    66    FVARIABLE  X92*X31*(100-XH10)/(20*X47)+1/2
519       SAVEVALUE  93,V66           ACRES PER DAY.
   * WEATHER FUNCTIONS AND PENALTIES.
520       SAVEVALUE  83,RN4           RANDOM NUMBER TO START THE SEASON.
   * TEST FOR GOOD OR BAD START.
521       TEST G     X83,X79,GOOD     IF RN <=PG , A GOOD START.
522 BAD   LOGIC R    13
523       SAVEVALUE  84,FN*17         LENGTH OF BAD PERIOD IN DAYS
524       SAVEVALUE  85+,X84          TOTAL DAYS
```

```
525         TEST GE     X85,K44,BAD1      IF END OF PERIOD NOT REACHED,
   * THIS NUMBER OF DAYS WILL VARY FROM 40 - 44 DAYS AFTER CUTTING HAS
   * STARTED (ON THE AVERAGE).
526         SAVEVALUE   85,K44            SET AT MAX.
527         TRANSFER    ,LOSSH
   * CALCULATE MATURITY LOSSES.
528 BAD1    ADVANCE     X84
  67        FVARIABLE   X17+X84*X86*1000
529         SAVEVALUE   17,V67            NEW MATURITY LOSS AC.-% X1000 .
530 GOOD    LOGIC S     13
531         SAVEVALUE   84,FN*18          LENGTH OF GOOD PERIOD IN DAYS.
532         ASSIGN      2,X84             NO. OF DAYS IN GOOD PERIOD.
533         ASSIGN      2+,K1             REQUIRED FOR LOOP TEST.
534         ASSIGN      3,K1              DAYS USED IN GOOD PERIOD.
535         ADVANCE     1                 FIRST DAY IN GOOD PERIOD.
536         SAVEVALUE   85+,K1            TOTAL DAYS THIS CUTTING.
537 WLOOP   TEST G      X86,X93,HLOSS     IF ACRES LEFT < AC. POSSIBLE PER DAY,
  68        FVARIABLE   X17+1000*(X86-X93)
   * CALCULATE MATURITY LOSSES.
   * NOTE : MAT. LOSS ONLY SUMMED TO THE LAST GOOD DAY OF THE PERIOD.
538         SAVEVALUE   17,V68            NEW MATURITY LOSS FIGURE.
539         SAVEVALUE   86-,X93           FIND ACRES LEFT TO DO ON NEXT DAY.
540         ASSIGN      3+,K1
541         ADVANCE     1                 ADVANCE CLOCK ONE DAY.
542         SAVEVALUE   85+,K1            TOTAL DAYS THIS CUTTING.
543         TEST GE     X85,K44,GOOD1     IF END OF PERIOD NOT REACHED,
544         SAVEVALUE   85,K44            SET AT MAX.
545         TRANSFER    ,LOSSH
546 GOOD1   LOOP        2,537             IF END OF PERIOD NOT REACHED,
   *                                      GO TO WLOOP.
547         TRANSFER    ,BAD
548 HLOSS   SAVEVALUE   86,K0             ALL ACRES CUT.
  69        FVARIABLE   ((X17/1000)-X85*X86)*X47/100+1/2
```

```
549 LOSSH SAVEVALUE  49,V69            EQUIV. MATURITY LOSS T.D.M. X10 .
    70    FVARIABLE  X49*(XH8*X1+XH9*X2*2)/10000+1/2
550       SAVEVALUE  3+,V70            MATURITY LOSSES IN CENTS.
551       SAVEVALUE  120+,X49          TOTAL T. DM.X10 EQUIV. LOSS .
   * FIND TOTAL DIGESTIBLE PROTEIN STORED.
    71    FVARIABLE  (XH15-(X86*(100-X85)/100))*X47*X118/5+1/2
552       SAVEVALUE  58+,V71           TOTAL D.P. STORED
   * NOTE: MATURITY FACTOR ONLY TEMPORARILY SET ASIDE.
   * FIND VALUE OF FEED LOST IF NOT CUT.
    72    FVARIABLE  X86*X47*(100-X85)*(XH8*X1+XH9*X2*2)/1000000+1/2
553       SAVEVALUE  15+,V72           CROP LOSSES IN CENTS.
   * FIND FIELD LOSSES.
    73    FVARIABLE  FN6*V71/(XH8*2)+1/2
    74    FVARIABLE  V73*(XH8*X1+XH9*X2*2)/100000+1/2
554 CCOST SAVEVALUE  4+,V74            FIELD LOSSES IN CENTS.
    75    FVARIABLE  (XH15-X36)*X47*(100-FN6)/100+1/2
555       SAVEVALUE  57+,V75           TOTAL TONS D.M.INTO STORAGE X10.
    76    FVARIABLE  V75*200/((100-XH10)*X31)+1/2
556       SAVEVALUE  52+,V76           TOTAL LOADS X10 .
    77    FVARIABLE  (X46+X32)*V76/1000+1/2
557       SAVEVALUE  49,V77            TEMPORARY STORAGE OF OPN. TIME (MIN.)
558       SAVEVALUE  55+,X49           OPERATING TIME OF FRG.HRVSTR.(MIN.)
    78    FVARIABLE  (X40+(X46+X32)/100)*V76/10+1/2
559       SAVEVALUE  53,V78            TOTAL TIME PER MAN(STD.MINUTES)
560       TRANSFER   P,K14,1
   *
   *            --  INITIALIZING SUBROUTINE  --
   *
561 INITL SAVEVALUE  99,K14,H
562       SAVEVALUE  14,FN10,H
563       SAVEVALUE  99,K45,H
564 INIT  SAVEVALUE  99+,K1,H          INCREMENT SAVEXH NO. COUNTER
565       ASSIGN     9,XH99
```

```
566        SAVEVALUE  *9,K0,H          SET INITIALLY TC ZERC
567        TEST G     FN10,K0,INIT1    IF NO RANGE GIVEN, GC TO INIT1
568        SAVEVALUE  90,FN10
569        TRANSFER   SBR,RNGEN,10
570        SAVEVALUE  *9,X90,H
571 INIT1  SAVEVALUE  *9+,FN8,H
   * IF THE LAST NUMBER IN THE LIST HAS BEEN PROCESSED, ZERO THE FULL-WORD
   * SAVEVALUES.
572        TEST E     P9,K78,INIT
573 IZERO  SAVEVALUE  99,K2,H          DC NOT ZERC SAVEX 1 CR 2.
574 IZER1  SAVEVALUE  99+,K1,H
575        ASSIGN     9,XH99
576        SAVEVALUE  *9,K0            ZERC FULL-WORD SAVEVALUE.
577        TEST E     XH99,K120,IZER1  IF SAVEX120 HAS NOT BEEN ZEROED, GO
   *                                   TC IZER1 .
578        MSAVEVALUE 1,1,38,K0        ZERC MSAVEX(1,1,38-42)
579        MSAVEVALUE 1,1,39,K0
580        MSAVEVALUE 1,1,40,K0
581        MSAVEVALUE 1,1,41,K0
582        MSAVEVALUE 1,1,42,K0
583        MSAVEVALUE 1,1,43,K0
   * RESET SOME LOGIC SWITCHES.
584        LOGIC R    1
585        LOGIC R    2
586        LOGIC R    3
587        LOGIC R    4
588        LOGIC R    11
589        TRANSFER   P,K15,1
   *
   *           --  TRACTOR CCST SUBROUTINE  --
   *
590 DTRCT  ASSIGN     7,K6             ROW 6 : DIESEL TRACTORS.
591        TRANSFER   ,TRCTR
```

```
592 GTRCT  ASSIGN     7,K5                ROW 5 : GASOLINE TRACTORS.
593 TRCTR  SAVEVALUE  13+,V6              $COST = (A + BX)/100
594        SAVEVALUE  20,V6
    16     FVARIABLE  X20*MX2(*7,15)/100
595        SAVEVALUE  22,V16              REPAIR RATE IN CENTS/HOUR.
596        SAVEVALUE  20,V7               DOLLARS PER ANNUM FIXED COST.
597        TRANSFER   P,K15,1
  *
  *             --    WIDTH DEPENDENT CAPACITY SUBROUTINE  --
  *
598 RATE1  SAVEVALUE  28,K0               DUMMY
    14     FVARIABLE  MH3(*16,4)*X25*10/(1000+XH38)+1/2
  * THE COLUMN NO. CAN BE CHANGED IF NECESSARY.
599        SAVEVALUE  28,V14              AC./HR. X1000 INCLUDING %R.A.
600        TRANSFER   P,K15,1
  *
  *             --    POWER DEPENDENT CAPACITY SUBROUTINE  --
  *
601 RATE2  SAVEVALUE  28,K0               DUMMY
    15     FVARIABLE  X24*X27*1000000/(XH29*X47*(1000+XH38))+1/2
602        SAVEVALUE  28,V15              AC./HR. X1000 INCLUDING %R.A.
603        TRANSFER   P,K15,1
  *
  *             --    TRANSIT SPEEDS SUBROUTINE  --
  *
604 SPEED  SAVEVALUE  83,MH6(*11,1),H     MIN.
605        SAVEVALUE  90,MH6(*11,2)       MAX.
606        SAVEVALUE  90-,XH83            RANGE
607        TRANSFER   SBR,RNGEN,10
608        SAVEVALUE  83+,X90,H           ROAD SPEED LOADED M.P.H. X10
609        SAVEVALUE  84,MH6(*11,4),H     MIN.
610        SAVEVALUE  90,MH6(*11,5)       MAX.
611        SAVEVALUE  90-,XH84            RANGE
```

```
612          TRANSFER    SBR,RNGEN,10
613          SAVEVALUE   84+,X90,H           ROAD SPEED EMPTY  M.P.H. X10
614          TRANSFER    P,K15,1
    *
    *              --  RNGEN SUBROUTINE  --
    *
    * GPSS SUBROUTINE TO PICK A POINT AT RANDOM FROM A VALUE SPECIFIED IN
    * THE MAINLINE, ROUNDING OFF INSTEAD OF TRUNCATING THE VALUE CHOSEN.
615 RNGEN SAVEVALUE  89,RN1,H            RANDOM NUMBER
  11         FVARIABLE   X90*(XH89+1)/1000+1/2
    * THE ' 1/2 ' INSURES THAT THE FIRST TRUNCATED DIGIT>=5 CAUSES THE NEXT
    * LARGEST INTEGER NUMBER TO BE CHOSEN.
616          SAVEVALUE   99,V11              TEMPORARY STORAGE.
    * MAKE SURE THAT THE RANGE IS NOT EXCEEDED.
617          TEST LE     X99,X90,RNEND
618          SAVEVALUE   90,X99              CHOSEN VALUE
619 RNEND    TRANSFER    P,K10,1
    *
    *              ---  SUMMARY    -----
    *
620 SUMRY    MSAVEVALUE  1,1,F1,K1000        FINAL NETWORK NODE NUMBER.
621          MSAVEVALUE  1,1,1,N4            TRANSACTION NUMBER.
622          MSAVEVALUE  1,1,17,X6           P.A. F.C. OF EQUIPMENT OTHER THAN
    *                                        TRACTORS, TRUCKS, AND WAGONS.
623          MSAVEVALUE  1,1,18,X31          NET TONS OF W.M. PER LOAD X2.
624          MSAVEVALUE  1,1,19,X120         EFFECTIVE MATURITY LOSS IN T. D.M.X10
625          MSAVEVALUE  1,1,20,X57          TONS OF D.M. X10 STORED.
626          MSAVEVALUE  1,1,21,X43          TONS OF D.M. X10 FED .
627          MSAVEVALUE  1,1,22,X58          LB. OF D.P. STORED.
  98         FVARIABLE   X43*((X57-X120)/X57)*X118/5+1/2
628          MSAVEVALUE  1,1,23,V98          LB. OF D.P. FED.
629          MSAVEVALUE  1,1,24,XH90         MAXIMUM NUMBER OF MEN (1).
630          MSAVEVALUE  1,1,25,XH91         MAXIMUM NUMBER OF MEN (2).
```

```
631        MSAVEVALUE 1,1,32,X55      TOTAL OPERATING MIN. OF HRVSTR.
632        MSAVEVALUE 1,1,33,X109     TOTAL OPERATING MIN. OF CUTTING UNIT.
633        MSAVEVALUE 1,1,34,X110     TOTAL OPERATING MIN. OF RAKING UNIT.
634        MSAVEVALUE 1,1,44,X13      TOTAL OUTLAY ($) FOR MCH. & EQMT.
635        MSAVEVALUE 1,1,45,X16      TOTAL OUTLAY FOR STORAGE FACILITIES.
636        MSAVEVALUE 1,1,46,X6       TTL. P.A.F.C. OF MCH. LESS TRNSPRTS.
    *                                 AND LESS TRACTORS OR TRUCKS.
637        MSAVEVALUE 1,1,47,X7       TOTAL P.A. MCH. & EQMT. OPERN COST.
638        MSAVEVALUE 1,1,48,X8       TOTAL P.A. STORAGE COST.
639        MSAVEVALUE 1,1,49,X9       TOTAL P.A. LABOUR COST.
640        MSAVEVALUE 1,1,50,X10      TOTAL P.A. DISTRIBUTION COST.
641        MSAVEVALUE 1,1,51,X3       MATURITY AND/OR WEATHER LOSSES.
642        MSAVEVALUE 1,1,52,X4       FIELD LOSSES.
643        MSAVEVALUE 1,1,53,X5       STORAGE LOSSES.
644        MSAVEVALUE 1,1,54,X15      LOSSES DUE TO UNHARVESTED ACRES.
645        MSAVEVALUE 1,1,55,XH81     MAX. NO. OF TRANSPORTING UNITS.
646        MSAVEVALUE 1,1,56,X50      NO. OF TRACTORS PACKING &/OR UNLDG.
    * IF S.P. HARVESTER USED, GO TO SUM1.
647        TEST G     MX1(1,38),K0,SUM1
648        SAVEVALUE  19,MX1(1,32)    TIME IN MINUTES.
649        SAVEVALUE  20,MX1(1,38)    PER ANNUM FIXED COST.
     97    FVARIABLE  X19*X20/(XH19*60)+1/2
650        MSAVEVALUE 1+,1,46,V97     TOTAL P.A. F.C. OF MCH. & EQMT.
    * IF NO TRACTOR USED FOR CUTTING OR RAKING, GO TO SUM2
651 SUM1   TEST G     MX1(1,39),K0,SUM2
652        SAVEVALUE  19,MX1(1,33)    TIME IN MINUTES.
653        SAVEVALUE  19+,MX1(1,34)   TIME IN MINUTES.
654        SAVEVALUE  20,MX1(1,39)    PER ANNUM FIXED COST.
655        MSAVEVALUE 1+,1,46,V97     TOTAL P.A. F.C. OF MCH. & EQMT.
    * IF NO P.T.O. POWER USED ON FORAGE BLOWER, GO TO SUM3.
656 SUM2   TEST G     MX1(1,40),K0,SUM3
657        GATE LS    20,SUM3         IF CUSTOM UNITS USED, GO TO SUM3
658        SAVEVALUE  19,MX1(1,35)    TIME IN MINUTES.
```

```
659        SAVEVALUE  20,MX1(1,40)     PER ANNUM FIXED COST.
660        MSAVEVALUE 1+,1,46,V97      TOTAL P.A. F.C. OF MCH. & EQMT.
   * IF NO PACKING OR UNLOADING TRACTORS, GO TO SUM4.
661 SUM3   TEST G     MX1(1,41),K0,SUM4
662        GATE LS    20,SUM4          IF CUSTOM UNITS USED, GO TO SUM4.
663        SAVEVALUE  19,MX1(1,36)     TIME IN MINUTES.
664        SAVEVALUE  20,MX1(1,41)     PER ANNUM FIXED COST.
    98     FVARIABLE  X19*X20/(X50*XH19*60)+1/2
665        MSAVEVALUE 1+,1,46,V98      TOTAL P.A. F.C. OF MCH. & EQMT.
   * IF CUSTOM CHARGES USED INSTEAD OF P.A.F.C. OF TRACTOR OR TRUCK
   * TRANSPORT(S), GO TO SUM6.
666 SUM4   TEST G     MX1(1,42),K0,SUM6
667        SAVEVALUE  50,XH81          NO. OF TRANSPORTING UNITS.
668        SAVEVALUE  19+,MX1(1,37)    TIME IN MINUTES.
669        SAVEVALUE  20,MX1(1,42)     PER ANNUM FIXED COST.
670        MSAVEVALUE 1+,1,46,V98      TOTAL P.A. F.C. OF MCH. & EQMT.
671 SUM6   MSAVEVALUE 1+,1,46,X43      ADD CUSTOM CHARGES.
672 SUM7   MSAVEVALUE 1+,1,46,X14      ADD P.A.F.C. OF WAGON(S) USED.
673        MSAVEVALUE 1,1,57,MX1(1,46) TOTAL PER ANNUM COST.
674        ASSIGN     8,K46
675        ASSIGN     2,K8
676 SLOOP  ASSIGN     8+,K1            INCREMENT VECTOR COORDINATE.
677        MSAVEVALUE 1+,1,57,MX1(1,*8)
          LOOP        2,676
    99     FVARIABLE  (X118*X1/(X118*X1+X119*X2*2))*MX1(1,57)*20/MX1(1,23)
678        MSAVEVALUE 1,1,58,V99       TOTAL COST PER TON D.P. FED ($)
679        PRINT      1,1,MX,1
   * TERMINATE THE YEAR.
680 TERM   SAVEVALUE  100,K365,H
681        SAVEVALUE  100-,M1,H
682        ADVANCE    XH100            TERMINATE THE YEAR.
           LIST
683        TERMINATE  1
```

```
START     2000                                       1580
END                                                  1581
```

APPENDIX H

GPSS PROGRAM FOR ALTERNATIVE SYSTEMS INCLUDING FIELD CURING

This program represents that portion of the macro-network including 'wilted alfalfa silage' and 'haylage' arcs or arrows. See figures 5 and 21 for the network of possibilities considered -- neither fully comprehensive nor all-inclusive -- for the Edmonton area. To limit the number of alternatives, changes could be made in the cards immediately following the TRANSFER PICK blocks that are of interest. Similarly, a half-word SAVEVALUE could be given a constant value instead of a ranging value by reducing the appropriate range coefficient (in FUNCTION 10) to zero. Note that introduction of additional individual machines into MSAVEVALUE 7 or 8 would require alterations in blocks referencing these matrices.

```
              G.P.S.S. PROGRAM - FIELD CURING PRIOR TO STORAGE
                     HAYLAGE AND WILTED ALFALFA SILAGE

        REALLOCATE BLO,800,FSV,120,HSV,120,VAR,110,FUN,35,LOG,20,TAB,0
        REALLOCATE XAC,2000,FAC,0,STO,0,BVR,0,CHA,0,QUE,0,COM,60000
        SIMULATE
1       GENERATE   ,,,5
        UNLIST
 * FOR LISTING OF HALF-WORD SAVEVALUES, FULL-WORD SAVEVALUES, LOGIC
 * SWITCHES, PARAMETERS, AND MATRIX SAVEVALUE 1,  SEE THE PROGRAM FOR
 * HIGH MOISTURE SILAGE AND DEHYDRATED ALFALFA.
 *
 *  MATRIX  MX2
 *   COLNO01 -- MULTIPLE OF UNITS USED IN X-COLUMNS
 *   COLNO02 -- MINIMUM OF X
 *   COLNO03 -- MAXIMUM OF X
 *   COLNO04 -- MEAN OF X
 *   COLNO05 -- STANDARD DEVIATION OF X
 *   COLNO06 -- MINIMUM OF Y
 *   COLNO07 -- MAXIMUM OF Y
 *   COLNO08 -- MEAN OF Y
 *   COLNO09 -- STANDARD DEVIATION OF Y
 *   COLNO10 -- REGRESSION INTERCEPT A  IN CENTS
 *   COLNO11 -- REGRESSION COEFFICIENT B  IN CENTS
 *   COLNO12 -- STANDARD ERROR OF B  IN CENTS
 *   COLNO13 -- ZERO-INTERCEPT LINEAR APPROXIMATION S  IN CENTS
 *   COLNO14 -- AMORTIZATION RATE IN % X10
 *   COLNO15 -- TOTAL REPAIR RATE % OF LIST PRICE PER 100 HOURS
 *   ROWNO01 -- FARM WAGONS(RUNNING GEAR LESS TIRES) - TONS PAYLOAD
 *   ROWNO02 -- SELF-UNLOADING FORAGE BOXES - CU.FT. CAPACITY
 *   ROWNO03 -- FARM TRUCKS(CHASSIS) - TONS PAYLOAD
 *   ROWNO04 -- CUSTOM TRUCK BOXES INSTALLED - NEAREST CU.FT.
 *   ROWNO05 -- GASOLINE TRACTORS - P.T.O. HP.
```

```
*    ROWNO06 -- DIESEL TRACTORS - P.T.O. HP.
*    ROWNO07 -- TOWER SILO UNLOADERS - SILO DIAMETER IN FEET
*   MATRIX  MF3
*    ROWS 1-5 IN AC./HR. X1000 .
*    ROWS 6-9 IN TONS W.M./HR. X100.
*    ROWNO01 -- MOWER
*    ROWNO02 -- SIDE-DELIVERY RAKE
*    ROWNO03 -- SELF-PROPELLED WINDROWER
*    ROWNO04 -- MULTI-TREATMENT MACHINE
*    ROWNO05 -- FORAGE HARVESTER
*    ROWNO06 -- LIGHT WEIGHT BALER ONLY
*    ROWNO07 -- LIGHT WEIGHT BALER PLUS WAGON
*    ROWNO08 -- HEAVY DUTY BALER ONLY
*    ROWNO09 -- HEAVY DUTY BALER PLUS WAGON
*    COLNO01 -- LOW SPEED/LOW FIELD EFFICIENCY (ROWS 1 - 5)
*    COLNO01 -- LOW CAPACITY/LOW FIELD EFFICIENCY (ROWS 6 TO 9)
*    COLNO02 -- LOW SPEED/HIGH FIELD EFFICIENCY (ROWS 1 - 5)
*    COLNO02 -- LOW CAPACITY/HIGH FIELD EFFICIENCY (ROWS 6 TO 9)
*    COLNO03 -- HIGH SPEED/LOW FIELD EFFICIENCY (ROWS 1 - 5)
*    COLNO03 -- HIGH CAPACITY/LOW FIELD EFFICIENCY (ROWS 6 TO 9)
*    COLNO04 -- HIGH SPEED/HIGH FIELD EFFICIENCY (ROWS 1 - 5)
*    COLNO04 -- HIGH CAPACITY/HIGH FIELD EFFICIENCY (ROWS 6 TO 9)
*   MATRICES  MF4 AND MF5
*    COLNO01 -- INITIAL COST IN DOLLARS
*    COLNO02 -- MAXIMUM WIDTH OF CUT IN FEET X100
*    COLNO03 -- P.T.O. HP.
*    COLNO04 -- PER ANNUM FIXED COST ($).
*    COLNO05 -- REPAIR COST IN CENTS/HOUR.
*   MATRIX  MF6
*    COLNO01 -- MINIMUM SPEED M.P.H. X10 FULL
*    COLNO02 -- MAXIMUM SPEED M.P.H. X10 FULL
*    COLNO04 -- MINIMUM SPEED M.P.H. X10 EMPTY
*    COLNO05 -- MAXIMUM SPEED M.P.H. X10 EMPTY
```

```
*   ROWNC01 -- FCRAGE TRANSPCRT UNITS - TRACTCR PCWER
*   ROWNC02 -- FCRAGE TRANSPCRT UNITS - TRUCK POWER
*  MATRIX  MF7
*   ROWNO01 -- INITIAL CCST IN DCLLARS
*   ROWNO02 -- WIDTH OF CUT IN FEET X100 (COLS 1 - 37)
*   ROWNC02 -- DIESEL F.T.C. HF. (COLS 38 - 39)
*   ROWNO03 -- PER ANNUM FIXED COST.($) .
*   ROWNC04 -- REPAIR COST IN CENTS/HOUR.
*   CCLNC01 TC CCLNC06-- MOWERS - TRAILER-TYPE
*   CCLNC07 TC CCLNC09-- CRIMPERS AND CONDITIONERS - TRAILER-TYPE
*   CCLNO10 TO CCLNC17-- MULTI-TREATMENT MACHINES - TRAILER-TYPE
*   CCLNC18 TO CCLNC22-- SIDE-DELIVERY RAKES - TRAILER-TYPE
*   CCLNC23 TO CCLNC24-- SIDE-DELIVERY RAKES - 3-POINT MOUNTED
*   CCLNC25 TC CCLNC37-- WHEEL RAKES - TRAILER-TYPE
*   COLNO38 TO CCLNC39-- SP FCRAGE HARVESTERS WITH HAY PICK-UP
*  MATRIX  MF8
*   ROWNC01 -- INITIAL CCST IN DCLLARS
*   ROWNC02 -- PER ANNUM FIXED COST ($) .
*   ROWNC03 -- REPAIR CCST IN CENTS/HOUR.
*   CCLNC01 TC CCLNC05-- P.T. H.D. FRG. HRVSTRS. FLYWL. WITH PICK-UP
*   COLNO06 TC CCLNC08-- P.T. H.D. FRG. HRVSTRS. CYLDR. WITH PICK-UP
*   COLNC09 TC CCLNC14-- FORAGE BLCWERS (AUGER-TYPE HOPPER)
*   CCLNC15 TO CCLNC19-- FORAGE BLCWERS (CONVEYCR-TYPE HCPPER)
*   CCLNC20            -- SIDE-TIP WAGCN.
*   COLNC21            -- CHAIN-&-FLIGHT CONVEYCR,62' FCR SILAGE.
*   COLNC22            -- CHAIN-&-FLIGHT CONVEYOR,18' FOR SILAGE.
* TENTHS-HF.,3 PHASE ,60 CYCLE ELECTRIC MOTORS--1800 R.P.M. -DRIP-PROOF
     1 FUNCTION    X101,D19
10    56    15    63    20    69    30    81    50    104   75    129
100   154   150   203   200   233   250   280   300   319   400   483
500   532   600   733   750   884   1000  1155  1250  1395  1500  2016
2000  2595
* TENTHS-HF. 3 PH.,60 CYC.,1800 R.P.M.,TOT.ENCLOSED,FAN-COOLED
```

```
     2 FUNCTION   X101,D19
10     75    15    83    20    89    30    108   50    137   75    171
100    205   150   323   200   388   250   480   300   544   400   957
500    1157  600   1504  750   1909  1000 .2399  1250  3100  1500  3528
2000   4544
* TENTHS-HP. 3 PH.,60 CYC.,1800 R.P.M.,TOT.ENCLOSED,EXPL.PROOF
     3 FUNCTION   X101,D19
10     122   15    132   20    141   30    173   50    213   75    291
100    325   150   465   200   530   250   681   300   745   400   1163
500    1355  600   1698  750   2168  1000  2658  1250  3459  1500  3891
2000   5041
* FULL H.P.  2 CYCLE GASOLINE ENGINE (NEAREST $5.)
     4 FUNCTION   X102,D10
2      65    3     65    4     70    5     75    6     105   7     110
8      160   9     215   10    285   18    590
* 100THS HP. 60 CYCLE ELECTRIC MOTORS-S.P. (NEAREST $5.)
     5 FUNCTION   X102,D6
25     40    33    50    50    65    75    80    100   100   150   120
* %M.C. VS. FIELD LOSSES % D.M.          HERMETICALLY SEALED TOWER SILO,
* UNSEALED TOWER SILO, AND SEALED BUNKER SILO.
     6 FUNCTION   XH10,D8
40     13    50    10    60    6     65    4     70    3     75    3
80     2     85    2
*  % M.C. VS. SEEPAGE,FERMENTATION,SURFACE LOSSES % D.M.
     7 FUNCTION   XH10,D8
40     7     50    6     60    6     65    6     70    8     75    11
80     16    85    20
* INITIAL OF LOWEST INITIAL VALUES OF SAVEXH ENTITIES. LIST NUMBER
* SUBJECT TO CHANGE.
     8 FUNCTION   XH99,L78
      11200       95          60          431         124         1560
      1620        149         1228        10          12          25
      30          0           300         10          1           10
```

```
   600        200        125        215        180        140
   775        104        105        105        0          8
   5          1          100        150        50         25
   13         125        300        400        800        35
   15         33         0          50         40         55
   72         75         75         75         65         55
   50         40         60         6          8          18
   20         50         50         0          76         55
   91         0          0          10         80         35
   35         35         35         35         60         0
  9 FUNCTION   XH10,D6
60    14    65    13    70    12    75    15    80    19    85    23
* RANGES THAT SAVEXH ENTITIES CAN TAKE OVER AND ABOVE VALUES IN FN8.
* LIST NUMBER SUBJECT TO CHANGE.
* THE '12' IN NO. 58 IS TO INSURE <=9.T. PER GROSS TRUCK LOAD, SINCE
* THE SIDE-TIP WAGON IS LIMITED TO APPROXIMATELY 8.T. W.M. CAPACITY,
* AND THE TRUCK BODY CAN BE ROUGHLY ESTIMATED AT 1. T.
  10 FUNCTION   XH99,L78
   0          0          0          0          0          0
   0          0          0          0          0          0
   0          10         0          0          0          0
   0          0          0          0          0          0
   0          21         48         35         0          0
   0          0          0          0          0          0
   0          0          0          20         10         15
   31         13         0          35         10         15
   8          10         10         15         15         15
   15         20         20         12         8          4
   30         50         10         0          25         27
   30         0          0          5          40         15
   15         15         15         15         40         0
* % M.C. VS. SEEPAGE, FERMENTATION,SURFACE LOSSES % D.M.
  11 FUNCTION   XH10,D5
```

```
65    14    70    12    75    13    80    17    85    21
*  PAGE 234 RICHEY--%M.C.(W.B.)VS. F SUBM X10--FIGURE FOR 80% EXTRAPLTD
   12 FUNCTION   XH10,C5
40    55    50    62    60    63    70    65    80    67
*  SILOS--TONS OF DRY MATTER CAPACITY, HIGH MOISTURE SILAGE BASIS.
* NUMBERS 1 - 7, WOOD STAVE; 8 - 23, CONCRETE STAVE; 24 - 55, STEEL OR
* LINED-STEEL TOWER SILOS.  NUMBERS 56 - 58, STEEL HORIZONTAL SILOS.
   13 FUNCTION   X100,L58
     41          50          64          65          79          100
     144         44          52          64          73          69
     82          100         115         130         147         144
     165         188         212         236         261         81
     108         66          98          131         93          138
     183         141         208         278         201         296
     394         123         152         226         299         63
     85          115         143         174         94          126
     170         212         257         124         153         160
     214         245         326         422
*  SILOS--INITIAL COST IN DOLLARS.
   14 FUNCTION   X100,L58
     5400        5800        6200        5800        6400        7000
     8600        4875        5225        5785        6400        6125
     6625        7250        7990        8850        9950        9250
     9990        10850       11725       12750       14000       17045
     18790       16783       18800       20900       19436       21968
     24242       23429       27017       30943       30850       35163
     38703       19000       20800       30000       33400       20016
     22517       23681       24947       26885       22542       26461
     27997       30187       34044       19200       20500       22000
     25000       40995       45797       50628
* FEET OF BLOWER PIPE REQUIRED : NOMINAL HEIGHT + 1 FT. IF A TOWER
* SILO, OR + 1 FT. + RADIUS + 1 FT. IF HORIZONTAL SILO.
   15 FUNCTION   X100,L58
```

```
     39          45          51          39          45          51
     51          41          46          51          56          41
     46          51          56          61          66          51
     56          61          66          71          76          51
     61          41          51          61          41          51
     61          41          51          61          41          51
     61          66          76          71          86          33
     41          49          57          65          33          41
     49          57          65          65          74          62
     74          45          45          45
* CENTS PER ANNUM FIXED COST. BASIS: 1% INSURANCE; 8% INTEREST; 1.2%
* REPAIRS IF WOOD OR CONCRETE, OR 0.6% REPAIRS IF STEEL.
* AMORT. RATE OF 5% FOR WOOD AND CONCRETE SILOS, AND A RATE OF 2.5% FOR
* THE STEEL AND LINED-STEEL SILOS.
    16 FUNCTION    X100,L58
     82080       88160       94240       88160       97280       10640
     130720      74100       79420       87932       97280       93100
     100700      110200      121448      134520      151240      14060
     151848      164920      178220      193800      212800      20624
     227359      203074      227480      252890      235176      26581
     293328      283491      326906      374410      373285      42547
     468306      229900      251680      363000      404140      24219
     272456      286540      301859      325308      272758      32017
     338764      365263      411932      251520      268550      28820
     302500      496039      554143      612598
*  SILOS--UNLOADER HORSE-POWER X100  --  SINGLE PHASE.
*        ARBITRARILY SET AT 5 HP. FOR <20'D.   , 7-1/2 HP. FOR >=24'D.
* FOR NUMBERS < 24, UNLOADER PRICE IS NOT INCLUDED IN THE SILO COST.
    17 FUNCTION    X100,L58
     500         500         500         500         500         500
     750         500         500         500         500         500
     500         500         500         500         500         750
     750         750         750         750         750         433
```

```
      433         433         433         433         633         633
      633         633         633         633         633         633
      633         500         500         500         500         750
      750         750         750         750         750         750
      750         750         750         825         825         825
      825         1050        1050        1050
*  SILOS--NO. OF FN. REFERRED TO WRT. D.M. STORAGE LOSSES.
    18 FUNCTION    X100,L58
      9           9           9           9           9           9
      9           9           9           9           9           9
      9           9           9           9           9           9
      9           9           9           9           9           7
      7           7           7           7           7           7
      7           7           7           7           7           7
      7           7           7           7           7           7
      7           7           7           7           7           7
      7           7           7           7           7           7
      7           7           7           7
* SILOS--DIAMETER OF SILO IN FEET (NOMINAL- NEXT LARGEST FOOT)
* USED ONLY WHERE AN UNLOADER COST FIGURE IS NEEDED, OR WHERE HORIZNTL.
* FLIGHT-&-CHAIN CONVEYOR IS UTILIZED DURING STORAGE PROCEDURES.
    19 FUNCTION    X100,L58
      16          16          16          20          20          20
      24          16          16          16          16          20
      20          20          20          20          20          24
      24          24          24          24          24          19
      19          21          21          21          25          25
      25          31          31          31          37          37
      37          20          20          25          25          22
      22          22          22          22          26          26
      26          26          26          20          20          24
      24
* IF WE USE A 62' F-&-C CONVEYOR AT A MAX. ANGLE OF ELEVATION OF 70
```

```
* DEGREES WITH 1 FT. OF CONVEYOR ALLOWED FOR CLEARANCE. A 57' SILO CAN
* BE FILLED IF AN AUXILIARY CROSS-CONVEYOR IS USED.
* SILOS--LIST NOS. THAT CAN BE USED WHEN F&C CONVYR. USED FOR STORING.
   20 FUNCTION    X103,L37
     1            2            3            4            5            6
     7            8            9            10           11           12
     13           14           15           18           19           24
     26           27           29           30           32           33
     35           36           42           43           44           45
     47           48           49           50           56           57
     58
* FLIGHT-&-CHAIN CONVEYOR - 62' LONG. 1' HEIGHT ALLOWED FOR CLEARANCE,
* 3'' X 21'' X 14'' FLIGHT; VOLUME PER FLIGHT (FT.**3  X1000)
* MAXIMUM FLIGHT VOLUME OF LEVEL FULL FLIGHT (ARBITRARILY ASSUMED)
   21 FUNCTION    X103,L37          ANGLE OF REPOSE = 40 DEGREES.
     510          364          204          510          364          204
     204          490          343          204          117          490
     343          204          117          204          117          204
     490          204          490          204          490          204
     490          204          510          490          257          107
     510          490          257          107          510          510
     510
   22 FUNCTION    X103,L37          ANGLE OF REPOSE = 50 DEGREES.
     510          510          406          510          510          406
     406          510          510          406          204          510
     510          406          204          406          204          406
     510          406          510          406          510          406
     510          406          510          510          469          179
     510          510          469          179          510          510
     510
   23 FUNCTION    X103,L37          ANGLE OF REPOSE = 60 DEGREES.
     510          510          510          510          510          510
     510          510          510          510          406          510
```

```
   510        510        406        510        406        510
   510        510        510        510        510        510
   510        510        510        510        510        364
   510        510        510        364        510        510
   510
* MAXIMUM FLIGHT VOLUME OF 120% OF LEVEL FULL FLIGHT (ARBITRARY )
  24 FUNCTION   X103,L37        ANGLE OF REPOSE = 40 DEGREES.
   587        427        204        587        427        204
   204        490        343        204        117        490
   343        204        117        204        117        204
   490        204        490        204        490        204
   490        204        587        490        257        107
   587        490        257        107        587        587
   587
  25 FUNCTION   X103,L37        ANGLE OF REPOSE = 50 DEGREES.
   587        587        406        587        587        406
   406        587        587        406        204        587
   587        406        204        406        204        406
   587        406        587        406        587        406
   587        406        587        587        469        179
   587        587        469        179        587        587
   587
  26 FUNCTION   X103,L37        ANGLE OF REPOSE = 60 DEGREES.
   587        587        587        587        587        587
   587        587        587        587        587        406
   587        587        587        406        587        406
   587        587        587        587        587        587
   587        587        587        587        587        364
   587        587        587        364        587        587
   587
  27 FUNCTION   X103,L37        HORIZONTAL CONVEYING DISTANCE FT.X10
   482        420        357        482        420        357
   357        472        414        357        261        472
```

```
        414        357        261        357        261        357
        472        357        472        357        472        357
        472        357        528        472        383        242
        528        472        383        242        550        550
        550
* ARBITRARY SET OF CRITERIA USED IN GENERATING THESE 'WORK' AND
* 'NON-WORK' WEATHER FUNCTIONS FOR FORAGE HARVESTING.
*  JUNE 20 THROUGH JULY 15
    32 FUNCTION   RN2,C15             BAD DAYS P=0.721
C      0     .287  1     .446  2     .594  3     .713  4     .782  5
.861   6     .891  7     .921  8     .931  9     .960  10    .970  11
.980   12    .990  14    1.000 17
    33 FUNCTION   RN3,C6              GOOD DAYS G=0.279
C      0     .494  1     .882  2     .965  3     .988  5     1.000 6
*  AUGUST 15 THROUGH SEPTEMBER 18
    34 FUNCTION   RN2,C15             BAD DAYS P=0.681
C      0     .264  1     .480  2     .600  3     .688  4     .768  5
.832   6     .856  7     .896  8     .952  9     .968  10    .976  11
.984   13    .992  16    1.000 19
    35 FUNCTION   RN3,C8              GOOD DAYS G=0.319
C      0     .508  1     .771  2     .907  3     .958  4     .983  5
.992   6     1.000 8
* INITIALIZE ALL MATRICES.
* INITIALIZE HALF-WORD MATRIX NO. 1.
      1 MATRIX     H,4,3              WAGONS,TRUCKS,S-U BOXES, DUMP BOXES.
        INITIAL    MH1(1-2,1),510/MH1(3-4,1),75
        INITIAL    MH1(1,2),59/MH1(1,3),270/MH1(2,2),181/MH1(2,3),61
        INITIAL    MH1(3,2),59/MH1(3,3),270/MH1(4,2),181/MH1(4,3),61
* INITIALIZE FULL-WORD MATRIX NO. 2.
      2 MATRIX     X,7,15             MAJOR MACHINERY MATRIX.
        INITIAL    MX2(1,1),2/MX2(1,2),6/MX2(1,3),15/MX2(1,4),10
        INITIAL    MX2(1,5),3/MX2(1,6),13450/MX2(1,7),28000
        INITIAL    MX2(1,8),19182/MX2(1,9),4674/MX2(1,10),4017
```

```
      INITIAL    MX2(1,11),2908/MX2(1,12),580/MX2(1,13),3680
      INITIAL    MX2(1,14),150/MX2(1,15),2
      INITIAL    MX2(2,1),1/MX2(2,2),298/MX2(2,3),700/MX2(2,4),477
      INITIAL    MX2(2,5),139/MX2(2,6),75000/MX2(2,7),240000
      INITIAL    MX2(2,8),176788/MX2(2,9),48491/MX2(2,10),111414
      INITIAL    MX2(2,11),137/MX2(2,12),113/MX2(2,13),370
      INITIAL    MX2(2,14),150/MX2(2,15),2
      INITIAL    MX2(3,1),2/MX2(3,2),3/MX2(3,3),25/MX2(3,4),10
      INITIAL    MX2(3,5),6/MX2(3,6),345700/MX2(3,7),940000
      INITIAL    MX2(3,8),495657/MX2(3,9),163164/MX2(3,10),254550
      INITIAL    MX2(3,11),45789/MX2(3,12),7074/MX2(3,13),94053
      INITIAL    MX2(3,14),150/MX2(3,15),2
      INITIAL    MX2(4,1),1/MX2(4,2),154/MX2(4,3),823/MX2(4,4),445
      INITIAL    MX2(4,5),159/MX2(4,6),31000/MX2(4,7),81500
      INITIAL    MX2(4,8),52625/MX2(4,9),12146/MX2(4,10),20822
      INITIAL    MX2(4,11),71/MX2(4,12),3/MX2(4,13),118
      INITIAL    MX2(4,14),150/MX2(4,15),2
      INITIAL    MX2(5,1),1/MX2(5,2),26/MX2(5,3),66/MX2(5,4),43
      INITIAL    MX2(5,5),11/MX2(5,6),350000/MX2(5,7),825000
      INITIAL    MX2(5,8),512533/MX2(5,9),151316/MX2(5,10),-39973
      INITIAL    MX2(5,11),12658/MX2(5,12),1384/MX2(5,13),11742
      INITIAL    MX2(5,14),150/MX2(5,15),1
      INITIAL    MX2(6,1),1/MX2(6,2),27/MX2(6,3),131/MX2(6,4),65
      INITIAL    MX2(6,5),27/MX2(6,6),377500/MX2(6,7),1635000
      INITIAL    MX2(6,8),814926/MX2(6,9),341358/MX2(6,10),24964
      INITIAL    MX2(6,11),12106/MX2(6,12),669/MX2(6,13),12487
      INITIAL    MX2(6,14),150/MX2(6,15),1
      INITIAL    MX2(7,1),1/MX2(7,2),16/MX2(7,3),30/MX2(7,4),22
      INITIAL    MX2(7,5),4/MX2(7,6),150000/MX2(7,7),241600
      INITIAL    MX2(7,8),191967/MX2(7,9),29207/MX2(7,10),80707
      INITIAL    MX2(7,11),5162/MX2(7,12),1535/MX2(7,13),8887
      INITIAL    MX2(7,14),100/MX2(7,15),0
* INITIALIZE HALF-WORD MATRIX NO. 3.
```

```
    3 MATRIX     H,9,4             CAPACITY FIGURES.
      INITIAL    MH3(1,1),318/MH3(1,2),361/MH3(1,3),500/MH3(1,4),565
      INITIAL    MH3(2,1),318/MH3(2,2),382/MH3(2,3),455/MH3(2,4),545
      INITIAL    MH3(3,1),318/MH3(3,2),361/MH3(3,3),409/MH3(3,4),464
      INITIAL    MH3(4,1),318/MH3(4,2),361/MH3(4,3),500/MH3(4,4),565
      INITIAL    MH3(5,1),200/MH3(5,2),300/MH3(5,3),279/MH3(5,4),419
      INITIAL    MH3(6,1),130/MH3(6,2),160/MH3(6,3),325/MH3(6,4),400
      INITIAL    MH3(7,1),110/MH3(7,2),140/MH3(7,3),275/MH3(7,4),350
      INITIAL    MH3(8,1),325/MH3(8,2),400/MH3(8,3),650/MH3(8,4),800
      INITIAL    MH3(9,1),275/MH3(9,2),350/MH3(9,3),550/MH3(9,4),700
* INITIALIZE HALF-WORD MATRIX NO. 4.
* F.A.F.C. CALCULATED ON THE BASIS OF 8% INTEREST, 0.5% INSURANCE
* 1% HOUSING,  AND AN AMORTIZATION PERIOD AS ALLOWED FOR FARM INCOME
* TAX PURPOSES.
    4 MATRIX     H,4,5             SP WINDROWERS LESS CONDITIONERS
      INITIAL    MH4(1,1),3315/MH4(1,2),1200/MH4(1,3),53/MH4(1,4),812
      INITIAL    MH4(2,1),3400/MH4(2,2),1400/MH4(2,3),35/MH4(2,4),833
      INITIAL    MH4(3,1),4120/MH4(3,2),1500/MH4(3,3),38/MH4(3,4),1009
      INITIAL    MH4(4,1),3544/MH4(4,2),1350/MH4(4,3),37/MH4(4,4),863
      INITIAL    MH4(1,5),133/MH4(2,5),136/MH4(3,5),165/MH4(4,5),142
* INITIALIZE HALF-WORD MATRIX NO. 5.
    5 MATRIX     H,4,5             SP WINDROWERS PLUS CONDITIONERS
      INITIAL    MH5(1,1),4392/MH5(1,2),1500/MH5(1,3),53/MH5(1,4),1076
      INITIAL    MH5(2,1),4520/MH5(2,2),1500/MH5(2,3),38/MH5(2,4),1107
      INITIAL    MH5(3,1),5520/MH5(3,2),800/MH5(3,3),28/MH5(3,4),1352
      INITIAL    MH5(4,1),4634/MH5(4,2),1350/MH5(4,3),38/MH5(4,4),1135
      INITIAL    MH5(1,5),176/MH5(2,5),181/MH5(3,5),221/MH5(4,5),185
* INITIALIZE HALF-WORD MATRIX NO. 6.
    6 MATRIX     H,2,6             TRANSIT SPEED FIGURES.
      INITIAL    MH6(1,1),80/MH6(1,2),150/MH6(1,3),0
      INITIAL    MH6(1,4),100/MH6(1,5),200/MH6(1,6),0
      INITIAL    MH6(2,1),200/MH6(2,2),300/MH6(2,3),0
      INITIAL    MH6(2,4),250/MH6(2,5),400/MH6(2,6),0
```

```
* INITIALIZE HALF-WORD MATRIX NO. 7.
    7 MATRIX     H,4,39            INDIVIDUAL MACHINES.
      INITIAL    MH7(1,1),685/MH7(1,2),742/MH7(1,3),849/MH7(1,4),800
      INITIAL    MH7(1,5),900/MH7(1,6),700/MH7(1,7),1185/MH7(1,8),1108
      INITIAL    MH7(1,9),1139/MH7(1,10),1750/MH7(1,11),2900
      INITIAL    MH7(1,12),2972/MH7(1,13),2890/MH7(1,14),2650
      INITIAL    MH7(1,15),3000/MH7(1,16),3086/MH7(1,17),3900
      INITIAL    MH7(1,18),810/MH7(1,19),898/MH7(1,20),850
      INITIAL    MH7(1,21),840/MH7(1,22),1024/MH7(1,23),755
      INITIAL    MH7(1,24),683/MH7(1,25),580/MH7(1,26),715
      INITIAL    MH7(1,27),805/MH7(1,28),905/MH7(1,29),685
      INITIAL    MH7(1,30),765/MH7(1,31),890/MH7(1,32),650
      INITIAL    MH7(1,33),887/MH7(1,34),597/MH7(1,35),822
      INITIAL    MH7(1,36),1015/MH7(1,37),1204
      INITIAL    MH7(1,38),24730/MH7(1,39),16570
      INITIAL    MH7(2,1-10),700/MH7(2,11),875/MH7(2,12),900
      INITIAL    MH7(2,13),900/MH7(2,14),900/MH7(2,15),925
      INITIAL    MH7(2,16),925/MH7(2,17),1200/MH7(2,18),800
      INITIAL    MH7(2,19),850/MH7(2,20),700/MH7(2,21),900
      INITIAL    MH7(2,22),950/MH7(2,23),800/MH7(2,24),800
      INITIAL    MH7(2,25),833/MH7(2,26),983/MH7(2,27),1133
      INITIAL    MH7(2,28),1283/MH7(2,29),792/MH7(2,30),958
      INITIAL    MH7(2,31),1125/MH7(2,32),750/MH7(2,33),1050
      INITIAL    MH7(2,34),833/MH7(2,35),800/MH7(2,36),1300
      INITIAL    MH7(2,37),1500/MH7(2,38),247/MH7(2,39),148
      INITIAL    MH7(3,1),134/MH7(3,2),145/MH7(3,3),166/MH7(3,4),156
      INITIAL    MH7(3,5),176/MH7(3,6),137/MH7(3,7),231/MH7(3,8),216
      INITIAL    MH7(3,9),222/MH7(3,10),341/MH7(3,11),566
      INITIAL    MH7(3,12),580/MH7(3,13),564/MH7(3,14),517
      INITIAL    MH7(3,15),585/MH7(3,16),602/MH7(3,17),761
      INITIAL    MH7(3,18),158/MH7(3,19),175/MH7(3,20),165
      INITIAL    MH7(3,21),164/MH7(3,22),200/MH7(3,23),147
      INITIAL    MH7(3,24),133/MH7(3,25),113/MH7(3,26),139
```

```
         INITIAL     MH7(3,27),157/MH7(3,28),176/MH7(3,29),134
         INITIAL     MH7(3,30),149/MH7(3,31),174/MH7(3,32),127
         INITIAL     MH7(3,33),173/MH7(3,34),116/MH7(3,35),160
         INITIAL     MH7(3,36),198/MH7(3,37),235
         INITIAL     MH7(3,38),6059/MH7(3,39),4060
         INITIAL     MH7(4,1),41/MH7(4,2),45/MH7(4,3),51/MH7(4,4),48
         INITIAL     MH7(4,5),54/MH7(4,6),42/MH7(4,7),47/MH7(4,8),44
         INITIAL     MH7(4,9),46/MH7(4,10),105/MH7(4,11),174
         INITIAL     MH7(4,12),178/MH7(4,13),173/MH7(4,14),159
         INITIAL     MH7(4,15),180/MH7(4,16),185/MH7(4,17),234
         INITIAL     MH7(4,18),32/MH7(4,19),36/MH7(4,20),34/MH7(4,21),34
         INITIAL     MH7(4,22),41/MH7(4,23),30/MH7(4,24),27/MH7(4,25),23
         INITIAL     MH7(4,26),29/MH7(4,27),32/MH7(4,28),36/MH7(4,29),27
         INITIAL     MH7(4,30),31/MH7(4,31),36/MH7(4,32),26/MH7(4,33),35
         INITIAL     MH7(4,34),24/MH7(4,35),33/MH7(4,36),41/MH7(4,37),48
         INITIAL     MH7(4,38),742/MH7(4,39),497
* INITIALIZE HALF-WORD MATRIX NO. 8.
       8 MATRIX      H,3,22            INDIVIDUAL MACHINES.
         INITIAL     MH8(1,1),3721/MH8(1,2),4900/MH8(1,3),3965
         INITIAL     MH8(1,4),4409/MH8(1,5),4047/MH8(1,6),3980
         INITIAL     MH8(1,7),3800/MH8(1,8),3800
         INITIAL     MH8(1,9),872/MH8(1,10),690/MH8(1,11),664
         INITIAL     MH8(1,12),1240/MH8(1,13),794/MH8(1,14),825
         INITIAL     MH8(1,15),1120/MH8(1,16),1050/MH8(1,17),1055
         INITIAL     MH8(1,18),1111/MH8(1,19),1185/MH8(1,20),3250
         INITIAL     MH8(1,21),1283/MH8(1,22),400
         INITIAL     MH8(2,1),726/MH8(2,2),956/MH8(2,3),773/MH8(2,4),860
         INITIAL     MH8(2,5),789/MH8(2,6),776/MH8(2,7),741/MH8(2,8),741
         INITIAL     MH8(2,9),170/MH8(2,10),135/MH8(2,11),129
         INITIAL     MH8(2,12),242/MH8(2,13),155/MH8(2,14),161
         INITIAL     MH8(2,15),218/MH8(2,16),205/MH8(2,17),206
         INITIAL     MH8(2,18),217/MH8(2,19),231/MH8(2,20),796
         INITIAL     MH8(2,21),250/MH8(2,22),78
```

```
        INITIAL    MH8(3,1),149/MH8(3,2),196/MH8(3,3),159/MH8(3,4),176
        INITIAL    MH8(3,5),162/MH8(3,6),159/MH8(3,7),152/MH8(3,8),152
        INITIAL    MH8(3,9),35/MH8(3,10),28/MH8(3,11),26/MH8(3,12),50
        INITIAL    MH8(3,13),32/MH8(3,14),33/MH8(3,15),45/MH8(3,16),42
        INITIAL    MH8(3,17),42/MH8(3,18),45/MH8(3,19),47/MH8(3,20),65
        INITIAL    MH8(3,21),16/MH8(3,22),5
      1 MATRIX     X,1,58          TRANSACTIONS VECTOR.
 * INITIALIZE SOME HALF-WORD SAVEVALUES AND ZERO ALL FULL-WORD VALUES.
        INITIAL    XH90-XH120,0/X1-X120,0
2       ADVANCE    2,2
3       TERMINATE
 * THIS INITIALIZATION PATH IS A METHOD OF CHANGING THE INITIAL RANDOM
 * NUMBER SEED BY VARYING THE NUMBER OF TRANSACTIONS THROUGH THIS PATH.
4       GENERATE   365,,2000,,100,F
5       TEST E     N4,K1,RANGE
 * INITIALLY,ALL LOGIC SWITCHES ARE AUTOMATICALLY RESET UNLESS OTHERWISE
 * SPECIFIED.
 * INITIALIZE SOME HALF-WORD SAVEVALUES.
6 START SAVEVALUE  99+,K1,H        INCREMENT SAVEXH NO. COUNTER.
7       ASSIGN     9,XH99
8       SAVEVALUE  *9,FN8,H        INITIAL VALUE
9       TEST E     P9,K44,START
  1     FVARIABLE  XH1-(XH2*XH5/XH4)*2000/XH3+1/2
  2     FVARIABLE  XH1*1000/XH4+1/2
  3     FVARIABLE  (1000000*XH2/XH3-XH5*X1/2)/XH7+1/2
  4     FVARIABLE  (MX2(*8,10)+MX2(*8,11)*(X31+2)*10*(100-XH10)/X35)/100
  5     FVARIABLE  (MX2(*8,10)+MX2(*8,11)*(X31+2)/2)/100+1/2
  6     FVARIABLE  (MX2(*7,10)+X49*MX2(*7,11))/100+1/2
  7     FVARIABLE  X20*(XH34/10+XH30+XH31/10+XH32)/100+1/2
  8     FVARIABLE  X19*X36
  9     FVARIABLE  X19*X36*(X21/10+XH30+XH31/10+XH32)+1/2
  10    FVARIABLE  X20*(X21/10+XH30+XH31/10+X23)+1/2
  13    FVARIABLE  X20*(100-XH14)/100+1/2
```

```
 100    FVARIABLE  X2C*(100-XH14)
  * FIND COST OF PROTEIN AND ENERGY.
10         TEST C      XH6,K0,UREA
11         SAVEVALUE   1,V1                COST OF PURCHASED PROTEIN
12         TRANSFER    ,SCRSE
13 UREA    SAVEVALUE   1,K0                FEED GRADE UREA ASCRIBED NO ENERGY
14         SAVEVALUE   1,V2                COST OF PURCHASED PROTEIN
15 SCRSE   SAVEVALUE   2,K0
16         SAVEVALUE   2,V3                COST OF PURCHASED ENERGY
  * ESTABLISH VALUES FROM A RANGE OF VALUES, ZERO FULL-WORD SAVEVALUES
  * AND SOME MATRIX SAVEVALUES, AND RESET SOME LOGIC SWITCHES.
17 RANGE   TRANSFER    SBR,INITL,15
18 FRCUT   MSAVEVALUE  1,1,2,K3            NETWORK NODE NUMBER.
19         ASSIGN      1,K3                NEXT COL. OF MX1 TO BE USED.
20         LOGIC S     1
21         TRANSFER    PICK,22,26
22         TRANSFER    ,MOWRK              MOWER,RAKE
23         TRANSFER    ,MCR                MOWER-CONDITIONER,RAKE
24         TRANSFER    ,MCW                MOW-CONDITION-WINDROWER
25         TRANSFER    ,SPWLC              SELF-PRO. WINDROWER LESS CONDITIONER
26         TRANSFER    ,SPWWC              SELF-PRO. WINDROWER WITH CONDITIONER
27 DCUT2   TRANSFER    PICK,28,29          TYPE OF TRANSPORT UNIT.
28         TRANSFER    ,OWNED              OWN TRANSPORT UNITS.
29         TRANSFER    ,HIRED              CUSTOM CHARGES FOR TRANSPORT POWER.
30 OWNED   LOGIC S     20
31         MSAVEVALUE  1,1,P1,K51          NETWORK NODE NUMBER.
32         ASSIGN      1+,K1               NEXT COL. OF MX1 TO BE USED.
33         TRANSFER    PICK,34,37          TYPE OF TRANSPORT UNIT.
34         TRANSFER    ,SUWGN              SIDE-UNLDG.(SELF-UNLDG.) WAGONS
35         TRANSFER    ,DPWGN              DUMP WAGONS
36         TRANSFER    ,SUTRK              SIDE-UNLDG.(SELF-UNLDG.) TRUCKS
37         TRANSFER    ,DPTRK              DUMP TRUCKS
38 HIRED   LOGIC R     20
```

```
39        MSAVEVALUE 1,1,P1,K52     NETWORK NODE NUMBER.                    557
40        ASSIGN     1+,K1          NEXT COL. OF MX1 TO BE USED.            558
41        TRANSFER   PICK,42,45     TYPE OF TRANSPORT UNIT.                 559
42        TRANSFER   ,SUWGN         SIDE-UNLDG.(SELF-UNLDG.) WAGONS         560
43        TRANSFER   ,DPWGN         DUMP WAGONS                             561
44        TRANSFER   ,STRKH         SIDE-UNLDG.(SELF-UNLDG.) TRUCKS         562
45        TRANSFER   ,DTRKH         DUMP TRUCKS                             563
46  STRKH ASSIGN     11,K3          ROW 3 OF HALF-WORD MATRIX 1.            564
47        MSAVEVALUE 1,1,P1,K73     NETWORK NODE NUMBER.                    565
48        ASSIGN     1+,K1          NEXT COL. OF MX1 TO BE USED.            566
49        LOGIC S    3              INDICATES TRUCK POWER                   567
50        TRANSFER   ,TRK2                                                  568
51  DTRKH ASSIGN     11,K4          ROW 4 OF HALF-WORD MATRIX 1.            569
52        MSAVEVALUE 1,1,P1,K74     NETWORK NODE NUMBER.                    570
53        ASSIGN     1+,K1          NEXT COL. OF MX1 TO BE USED.            571
54        LOGIC S    3              INDICATES TRUCK POWER                   572
55        LOGIC S    4              INDICATES A DUMP UNIT                   573
56        TRANSFER   ,TRK2                                                  574
57  SUWGN ASSIGN     11,K1          ROW 1 OF HALF-WORD MATRIX 1.            575
58        MSAVEVALUE 1,1,P1,K71     NETWORK NODE NUMBER.                    576
59        ASSIGN     1+,K1          NEXT COL. OF MX1 TO BE USED.            577
60        ASSIGN     8,K2                                                   578
61        SAVEVALUE  20,V4                                                  579
62        TRANSFER   ,WGN1                                                  580
63  DPWGN ASSIGN     11,K2          ROW 2 OF HALF-WORD MATRIX 1.            581
64        MSAVEVALUE 1,1,P1,K72     NETWORK NODE NUMBER.                    582
65        ASSIGN     1+,K1          NEXT COL. OF MX1 TO BE USED.            583
66        LOGIC S    4              INDICATES A DUMP UNIT                   584
67        ASSIGN     8,K4                                                   585
68        SAVEVALUE  20,V4                                                  586
69        SAVEVALUE  20+,K550       ADD THE I.C. OF 10.T. HOIST .           587
70        TRANSFER   ,WGN1                                                  588
71  WGN1  SAVEVALUE  31,XH59        TONS W.M./LOAD X2                       589
```

```
 72        ASSIGN      8,K1
 73        SAVEVALUE   20+,V5            $ INITIAL COST OF WGN. R. GEAR.
 74        TRANSFER    ,TPVAL            TRANSPORT UNIT VALUES
 75 SUTRK  ASSIGN      11,K3             ROW 3 OF HALF-WORD MATRIX 1.
 76        MSAVEVALUE  1,1,P1,K73        NETWORK NODE NUMBER.
 77        ASSIGN      1+,K1             NEXT COL. OF MX1 TO BE USED.
 78        LOGIC S     3                 INDICATES TRUCK POWER
 79        ASSIGN      8,K2
 80        SAVEVALUE   20,K52            ADD THE I.C. OF P.T.O. INSTALLATION.
 81        TRANSFER    ,TRK1
 82 DFTRK  ASSIGN      11,K4             ROW 4 OF HALF-WORD MATRIX 1.
 83        MSAVEVALUE  1,1,P1,K74        NETWORK NODE NUMBER.
 84        ASSIGN      1+,K1             NEXT COL. OF MX1 TO BE USED.
 85        LOGIC S     3                 INDICATES TRUCK POWER
 86        LOGIC S     4                 INDICATES A DUMP UNIT
 87        ASSIGN      8,K4
 88        SAVEVALUE   20,K550           ADD THE I.C. OF 10.T. HOIST .
 89        TRANSFER    ,TRK1
 90 TRK1   SAVEVALUE   31,XH58           TONS W.M./LOAD X2
 91        SAVEVALUE   20+,V4
 92        ASSIGN      8,K3
 93        SAVEVALUE   20+,V5
 94 TRK2   SAVEVALUE   31,XH58           THIS DUPL. REQ'D FOR HIRED TRUCKS.
  * ADD P.A. F.C. OF SIDE TIP WAGON.
 95        SAVEVALUE   13+,MH8(1,20)     UPDATE TOTAL OUTLAY FOR MACHINERY.
 96        SAVEVALUE   49,MH8(2,20)      P.A.F.C. IN DOLLARS.
 97        SAVEVALUE   14+,V100          PER ANNUM FIXED COST OF TRANSPORTS.
 98        SAVEVALUE   22+,MH8(3,20)     REPAIR RATE CENTS/HR.
  * NOTE: TIME OF OPERATION OF SIDE-TIP WAGON IS EQUAL TO THAT OF THE
  * FORAGE HARVESTER.
 99 TPVAL  SAVEVALUE   32,MH1(*11,1)     HITCH-UNHITCH TIME MIN./LD. X100
100        SAVEVALUE   33,MH1(*11,3)     UNLOADING TIME MIN./TON X100
  *                                      OR DUMP CYCLE MIN./LOAD X100
```

```
101        SAVEVALUE  34,MH1(*11,2)    MANOEUVERING TIME MIN./LD. X100
102        GATE LR    4,DUMP1          IF A DUMP UNIT, GO TO DUMP1
   20      FVARIABLE  X33*X31/2+1/2
103  SUNL1 SAVEVALUE  33,V20           UNLOADING TIME MIN./LD. X100
104        TRANSFER   ,TRNFC           TRANSPORT FIXED COST - PER UNIT.
105  DUMP1 SAVEVALUE  35,K8            RHO SUB DM APPROXIMATION--A.F.'57
106  TRNFC GATE LS    20,FHTSP         IF HIRED TRNS. UNITS, GO TO FHTSP.
107        SAVEVALUE  36,V13           $ INITIAL COST PER UNIT.
   * FORAGE HARVESTER : TRANSPORT SPEEDS.
108  FHTSP GATE LR    3,BBB            IF NOT TRACTOR DRAWN, GO TO BBB
   * FIND AVERAGE ROAD SPEED LOADED AND EMPTY FOR TRACTORS WITH FRG. WAGON
109        ASSIGN     11,K1
110        TRANSFER   SBR,SPEED,15
111        TRANSFER   ,FHRD2
   * FIND AVERAGE ROAD SPEED LOADED AND EMPTY FOR TRUCKS WITH FORAGE BOXES
112  BBB   ASSIGN     11,K2
113        TRANSFER   SBR,SPEED,15
114        TRANSFER   ,FHRD2
115  FHRD2 TRANSFER   ,PRAT2           PRE-CUT RATE DETERMINATION 2
   * FIND P.A.F.C. OF CONDITIONER.
116  MCR   LOGIC S    5                INDICATES MOWER-CONDITIONER,RAKE SEQ.
117        MSAVEVALUE 1,1,P1,K31       NETWORK NODE NUMBER.
118        ASSIGN     1+,K1            NEXT COL. OF MX1 TO BE USED.
119        ASSIGN     12,K1
120        ASSIGN     11,K7
121        SAVEVALUE  90,K2
122        TRANSFER   SBR,PCMCH,15
123        TRANSFER   ,MOWR1
   * FIND P.A.F.C. OF MOWER.
124  MOWRK ASSIGN     12,K2
125        MSAVEVALUE 1,1,P1,K30       NETWORK NODE NUMBER.
126        ASSIGN     1+,K1            NEXT COL. OF MX1 TO BE USED.
127  MOWR1 ASSIGN     16,K1            FOR CAPACITY MATRIX REFERENCE
```

```
128        ASSIGN     11,K1
129        SAVEVALUE  9C,K5
130        TRANSFER   SBR,FCMCH,15
131        SAVEVALUE  105,MH7(2,*11)  WIDTH  FT. X100
132        SAVEVALLE  1C6,XH72        F.T.O. HP.
   * FIND P.A.F.C. OF RAKE.
133        TRANSFER   PICK,134,135
134        TRANSFER   ,SDRAK          SIDE-DELIVERY RAKE
135        TRANSFER   ,WLRAK          WHEEL RAKE
136 SDRAK  MSAVEVALLE 1,1,P1,K33      NETWORK NODF NUMBER.
137        ASSIGN     1+,K1           NEXT COL. OF MX1 TO BE USED.
138        ASSIGN     11,K18
139        SAVEVALLE  9C,K6
140        TRANSFER   ,RAKE
141 WLRAK  MSAVEVALLE 1,1,P1,K34      NETWORK NODE NUMBER.
142        ASSIGN     1+,K1           NEXT CCL. OF MX1 TO BF USED.
143        ASSIGN     11,K25
144        SAVEVALUE  90,K12
145 RAKE   LOGIC S    6               TEST LATER FOR RETURNING OF WINDROWS
   * INITIAL ANC PER ANNUM FIXEC CUSTS OF EQUIPMENT.
146        TRANSFER   SBR,FCMCH,15
   * CALCULATE RAKING CAPACITY ANC OPERATING COST.
    21     FVARIAELE  MH3(2,1)*MH7(2,*11)*10/(1000+XH38)+1/2
    22     FVARIAELE  XH73*XH65*XH22*115/1000000+MH7(4,*11)+1/2
147        SAVEVALUE  77,V21          RAKING CAP'Y IN STD.AC./HR. X1000
148        SAVEVALUE  78,V22          OPERATING COST OF TRACTOR ON RAKE
149        TRANSFER   ,TRPAC          TRACTOR PER ANNUM FIXED COST.
   * FIND P.A.F.C. OF MOW-CONDITICN-WINDROW UNIT.
150 MCW    ASSIGN     12,K3
151        MSAVEVALLE 1,1,P1,K35      NETWORK NODE NUMBER.
152        ASSIGN     1+,K1           NEXT COL. OF MX1 TO BE USED.
153        ASSIGN     11,K10
154        SAVEVALLE  9C,K7
```

```
    * INITIAL AND PER ANNUM FIXED COSTS OF EQUIPMENT.
155          TRANSFER    SER,PCMCH,15
156          SAVEVALUE   105,MH7(2,*11)  WIDTH  FT. X100
157          ASSIGN      16,K4           FOR CAPACITY MATRIX REFERENCE
158          SAVEVALUE   106,XH74        P.T.O. HP.
159          TRANSFER    ,TRPAC          TRACTOR PER ANNUM FIXED COST.
    * SELF-PROPELLED WINDROWER LESS CONDITIONER.
160 SPWLC    ASSIGN      12,K4           HALF-WORD MATRIX NUMBER
161          MSAVEVALUE  1,1,P1,K36      NETWORK NODE NUMBER.
162          ASSIGN      1+,K1           NEXT COL. OF MX1 TO BE USED.
163          SAVEVALUE   45,K1,H         LOWEST NUMBER
164          SAVEVALUE   90,K3           RANGE
165          TRANSFER    ,SPW
    * SELF-PROPELLED WINDROWER PLUS CONDITIONER.
166 SPWWC    ASSIGN      12,K5           HALF-WORD MATRIX NUMBER
167          MSAVEVALUE  1,1,P1,K37      NETWORK NODE NUMBER.
168          ASSIGN      1+,K1           NEXT COL. OF MX1 TO BE USED.
169          SAVEVALUE   45,K1,H         LOWEST NUMBER
170          SAVEVALUE   90,K3           RANGE
171 SPW      TRANSFER    SBR,RNGEN,10
172          SAVEVALUE   45+,X90,H       INDIRECT ADDRESS
173          SAVEVALUE   19,K1           ONE UNIT
174          ASSIGN      16,K3           FOR CAPACITY MATRIX REFERENCE
175          SAVEVALUE   13+,MH*12(XH45,1) INITIAL COST OF 1 UNIT. $.
    * NOTE: ASSUMING THAT ALL FIXED COSTS ARE CHARGED TO FORAGE ENTERPRISE.
176          SAVEVALUE   20,MH*12(XH45,4) $ P.A.F.C.
177          SAVEVALUE   22,MH*12(XH45,5)  REPAIR COST IN CENTS/HOUR.
178          SAVEVALUE   6+,V100         UPDATE TOTAL P.A. MCH. & EQMT. COST
179          SAVEVALUE   105,MH*12(XH45,2) WIDTH  FT. X100
180          SAVEVALUE   106,MH*12(XH45,3) P.T.O. HP.
181          TRANSFER    ,CCOC           CUTTING CAPACITY AND O.C.
    * FIND P.A. F.C. OF TRACTOR ON CUTTING UNIT.
182 TRPAC    SAVEVALUE   49,X106         A NECESSARY DUMMY LABEL.
```

```
183          SAVEVALUE  19,X22              TEMPORARY STORAGE OF REPAIR RATE.
184          TRANSFER   SBR,GTRCT,15
185          SAVEVALUE  22+,X19             TOTAL REPAIR RATE IN CENTS/HOUR.
186          MSAVEVALUE 1,1,39,V100         P.A. F.C. OF TRCTR. ON CUTTING UNIT.
    * FIND STANDARD CUTTING CAPACITY IN AC./HR. X1000 AND O.C. IN CENTS/HR.
      23     FVARIABLE  MH3(*16,1)*X105*10/(1000+XH38)+1/2
      24     FVARIABLE  X106*XH65*XH22*115/1000000+X22+1/2
187 CCCC     SAVEVALUE  107,V23             STD. AC./HR. X1000 CUTTING.
188          SAVEVALUE  108,V24             OPERATING COST  CENTS/HR.
189          TRANSFER   ,HRVST
190 AAA      SAVEVALUE  47,XH16             YIELD OF FIRST CUT
191 AAAP1    SAVEVALUE  27,XH55             FIELD EFFICIENCY
192          TRANSFER   SBR,RATE2,15        FIND POWER-DEPENDENT RATE
193          SAVEVALUE  49,X28              TEMPORARY STORAGE OF RATE.
194          ASSIGN     16,K5
195          SAVEVALUE  25,X105             CUTTING WIDTH IN FT.X100   .
196          TRANSFER   SBR,RATE1,15        FIND WIDTH-DEPENDENT RATE
    * NOTE: MORE TO DOUBLE CHECK ON S-P UNITS THAN P-T UNITS.
197          TEST G     X28,X49,AAAP2
198          SAVEVALUE  28,X49              SMALLER AC/HR.X1000 TAKEN AS LIMITING
199 AAAP2    GATE LR    11,SLGW1            IF 2ND OR LATER CUT, GOTO SLGW1
200          TRANSFER   ,DCUT2              DETERMINE TYPE OF TRANSPORT UNIT
      25     FVARIABLE  X34*(1000+XH38)/1000+1/2
      26     FVARIABLE  X38*(1000+XH38)/1000+1/2
      27     FVARIABLE  XH17*10*(1/XH83+1/XH84)*6000+1/2
      28     FVARIABLE  X32*(1000+XH39)/1000+1/2
201 SLGWD    SAVEVALUE  34,V25              STD. MANOEUVERING TIME MIN./LOAD X100
202          SAVEVALUE  38,V26              STD. UNLOADING TIME MIN./LOAD X100
203          SAVEVALUE  35,V27              TRAVELLING TIME MIN./LOAD X100
    * NOTE: ONLY IF A %R.A. IS INCLUDED IN THE ORIGINAL XH83 AND XH84.
204          SAVEVALUE  32,V28              STD. HITCH-UNHITCH TIME MIN./LD. X100
205          ASSIGN     17,K32              BAD DAYS FN. NO.
206          ASSIGN     18,K33              GOOD DAYS FN. NO.
```

```
207        SAVEVALUE  79,K279           PROBABILITY OF A GOOD DAY X1000        755
208        SAVEVALUE  89,K3             MAX. NO. OF TRANSPORTING UNITS         756
209        ADVANCE    173,2             JUNE 22 +/- 2 DAYS                     757
210        TRANSFER   SER,SPCUT,14                                             758
211        SAVEVALUE  51,XH81           NO. OF TRANSPORTING UNITS -FIRST CUT   759
212        SAVEVALUE  80,X51,H          NO. OF TRANSPORTING DRIVERS            760
213        SAVEVALUE  80+,K1,H          PLUS ONE HARVESTER OPERATOR            761
214        SAVEVALUE  90,XH80,H         FIRST CUT.                             762
215        MSAVEVALUE 1,1,26,X86        ACRES NOT HARVESTED(1).                763
216        MSAVEVALUE 1,1,30,X53        STD. MIN./MAN DURING HARVESTING(1).    764
217        MSAVEVALUE 1,1,28,X85        DAYS TO HARVEST (1).                   765
218        GATE LS    20,HTRN1          IF HIRED TRNS. UNITS, GO TO HTRN1.     766
     29    FVARIABLE  (XH80*X53+X109+X110)*XH20/60+1/2                         767
219        SAVEVALUE  9+,V29            UPDATE PER ANNUM LABOUR COST           768
220        TRANSFER   ,CUT2                                                    769
221 HTRN1  SAVEVALUE  80-,X50           CUSTOM CHARGES INCLUDE DRIVER WAGES.   770
222        SAVEVALUE  81-,X51           CUSTOM CHARGES INCLUDE DRIVER WAGES.   771
223        SAVEVALUE  9+,V29            UPDATE PER ANNUM LABOUR COST           772
224 CUT2   SAVEVALUE  47,XH18           YIELD OF SECOND CUT                    773
225        LOGIC S    11                SECOND CUT INDICATED                   774
226        TRANSFER   ,AAAF1                                                   775
227 SLOW1  ASSIGN     17,K34            BAD DAYS FN. NO.                       776
228        ASSIGN     18,K35            GOOD DAYS FN. NO.                      777
229        SAVEVALUE  79,K319           PROBABILITY OF A GOOD DAY X1000        778
    * NOTE : ENSURE THAT THE CLOCK TIME AT END OF FIRST CUT IS NOT >=229.      779
230        SAVEVALUE  100,K229,H                                               780
231        SAVEVALUE  100-,M1,H         CLOCK TIME                             781
232        ADVANCE    XH100,2           AUG. 17 +/- 2 DAYS                     782
233        TRANSFER   SER,SPCUT,14                                             783
234        SAVEVALUE  54,XH81                                                  784
235        SAVEVALUE  80,X54,H                                                 785
236        SAVEVALUE  80+,K1,H                                                 786
237        SAVEVALUE  91,XH80,H         SECOND CUT.                            787
```

```
238        MSAVEVALUE 1,1,27,X86      ACRES NOT HARVESTED(2).
239        MSAVEVALUE 1,1,31,X53      STD. MIN./MAN DURING HARVESTING(2).
240        MSAVEVALUE 1,1,29,X85      DAYS TO HARVEST (2).
241        GATE LS    20,HTRN2        IF HIRED TRNS. UNITS, GO TO HTRN2.
242        SAVEVALUE  9+,V29          UPDATE PER ANNUM LABOUR COST
243        TRANSFER   ,TTEST
244 HTRN2  SAVEVALUE  80-,X50         CUSTOM CHARGES INCLUDE DRIVER WAGES.
245        SAVEVALUE  81-,X51         CUSTOM CHARGES INCLUDE DRIVER WAGES.
246        SAVEVALUE  9+,V29          UPDATE PER ANNUM LABOUR COST
 * FIND THE LARGEST NO. OF TRANSPORTING UNITS REQUIRED.
247 TTEST  TEST LE    XH81,X51,FHOPC
248        SAVEVALUE  81,X51,H        IF X51 IS THE  LARGER  NO. OF UNITS.
 * FIND FORAGE HARVESTING OPERATING COST ASSUMING NO OPERATION DURING
 * DELAYS THAT OCCUR DUE TO WAITING FOR A TRANSPORT UNIT.
249 FHOPC  SAVEVALUE  29,XH66         AVG. DIESEL CONS. GAL/PTO.HP-HR X1000
250        SAVEVALUE  30,XH23         COST OF DIESEL CENTS/GAL. X10
 * FIND OPERATING COST OF POWER UNIT ON CUTTING UNIT.
 30        FVARIABLE  X109*X108/60+1/2
251        SAVEVALUE  7+,V30          UPDATE TOTAL MCH. OPN. COST
252        GATE LS    6,FOPC          IF RAKE NOT IN THE SEQUENCE, GO TO
 * FIND OPERATING COST OF TRACTOR ON RAKE.
 31        FVARIABLE  X110*X78/60+1/2
253        SAVEVALUE  7+,V31          UPDATE TOTAL MCH. OPN. COST
 * NOTE: IN CALCULATING POWER UNIT OPERATING COST, THE COST OF OIL,
 * LUBRICANTS, ETC. IS ASSUMED TO BE 15% OF FUEL COST (A.S.A.E. 1969
 * YEARBOOK).
 32        FVARIABLE  X55*X24*X29*X30*115/(60000*1000)+X55*X22/60+1/2
254 FOPC   SAVEVALUE  7+,V32          UPDATE TOTAL MACH. OPN. COST
255        GATE LR    20,PTRNS        IF OWN TRNS. UNITS, GO TO PTRNS.
 * FIND CUSTOM CHARGES FOR THE TRANSPORT POWER UNITS.
256        SAVEVALUE  19,XH81         NO. OF TRANSPORTING UNITS.
257        GATE LR    3,HTRNS         IF TRUCK POWER, GO TO HTRNS.
 * FOR TRACTOR POWER,
```

```
258         SAVEVALUE  20,XH40          CENTS PER HOUR CHARGED.
259         TRANSFER   ,HTRN3
   * FOR TRUCK POWER,
260 HTRNS  SAVEVALUE  20,XH41          CENTS PER HOUR CHARGED.
    18      FVARIABLE  (X51*MX1(1,28)+X54*MX1(1,29))*X20*X81
261 HTRN3  MSAVEVALUE 1,1,43,V18
262         GATE LS    3,WGN3           IF WAGONS USED, GO TO WGN3.
263         TRANSFER   ,CCC1
   * FIND PER ANNUM FIXED COST OF TRANSPORT UNITS.
264 PTRNS  SAVEVALUE  19,XH81          NO. OF TRANSPORTING UNITS.
265         GATE LR    3,TPAFC          IF TRUCK POWER, GO TO TPAFC.
266 WGN3   SAVEVALUE  19+,K1           ADD THE UNIT FILLING.
267         SAVEVALUE  21,XH34          AMORT. RATE FOR WAGONS.
268         SAVEVALUE  13+,V8           UPDATE TOTAL OUTLAY FOR MACHINERY.
269         SAVEVALUE  22,MX2(1,15)     REPAIR RATE IN % OF LIST /100 HOURS.
    101     FVARIABLE  X22*V8/100
270         SAVEVALUE  111,V101         REPAIR RATE IN CENTS/HOUR.
271         SAVEVALUE  14+,V9           UPDATE P.A.F.C. OF TRNSPRT. UNITS
272         TRANSFER   ,FHTOC
273 TPAFC  SAVEVALUE  21,XH34          AMORT. RATE  %X10.
274         SAVEVALUE  13+,V8           UPDATE TOTAL OUTLAY FOR MACHINERY.
275         SAVEVALUE  22,MX2(3,15)     REPAIR RATE IN % OF LIST /100 HOURS.
276         SAVEVALUE  111,V101         REPAIR RATE IN CENTS/HOUR.
277         MSAVEVALUE 1+,1,42,V9       UPDATE P.A.F.C. OF TRNSPRT. UNITS.
   * FIND OPERATING COST OF TRANSPORT UNITS.
278 FHTOC  GATE LR    3,CCC            IF NOT TRACTOR DRAWN, GO TO CCC
    33      FVARIABLE  X52*(X32+X34+X35+X38)/1000+1/2
279         MSAVEVALUE 1,1,37,V33       TOTAL OPERATING MIN. OF TRANS. UNITS.
280         GATE LS    20,CNVFC         IF HIRED TRNS. UNITS, GO TO CNVFC.
    34      FVARIABLE  XH76*XH65*XH22*V33*115/(60000*1000)+1/2
281         SAVEVALUE  7+,V34           UPDATE TOTAL MCH. OPERATING COST
   * FIND P.A. F.C. OF TRACTORS ON TRANSPORT UNITS.
282         SAVEVALUE  49,XH76          P.T.O. HP. ON TRANSPORT UNITS.
```

```
283        SAVEVALUE  19,XH81            NO. OF TRACTORS.
284        TRANSFER   SBR,GTRCT,15
285        SAVEVALUE  13-,V6             DO NOT UPDATE OUTLAY YET.
286        SAVEVALUE  36,X20
287        SAVEVALUE  13+,V8             UPDATE TOTAL OUTLAY FOR MACHINERY
288        SAVEVALUE  36,V100            P.A. F.C. OF ONE UNIT.
289        SAVEVALUE  22,MX2(5,15)       REPAIR RATE IN % OF LIST /100 HOURS.
290        SAVEVALUE  111+,V101          REPAIR RATE IN CENTS/HOUR.
291        MSAVEVALUE 1+,1,42,V8         P.A. F.C. OF TRCTR(S) OR TRUCK(S)
292        TRANSFER   ,CCC2
    35     FVARIABLE  ((X34+X32)/6000+XH17*10/XH84)*XH84/XH69+1/2
    36     FVARIABLE  (V35+(X38/6000+XH17*10/XH83)*XH83/XH68)*X52*XH22/100
293 CCC    SAVEVALUE  7+,V36             UPDATE TOTAL MCH. OPN. COST
    81     FVARIABLE  X52*(X32+X34+X38)/100+1/2
    82     FVARIABLE  V81+X52*XH17*10*60*(1/XH84+1/XH83)+1/2
294 CCC1   MSAVEVALUE 1,1,37,V82         TOTAL OPERATING MIN. OF TRANS. UNITS.
295        GATE LS    20,CNVFC           IF HIRED TRNS. UNITS, GO TO CNVFC.
   * ADD REPAIR COSTS TO OPERATING COSTS.
    102    FVARIABLE  MX1(1,37)*X111/(XH81*60)+1/2
296 CCC2   SAVEVALUE  7+,V102            UPDATE TOTAL MCH. OPERATING COSTS.
297        SAVEVALUE  49,XH76            PTO H.P.
298        TRANSFER   SBR,GTRCT,15
299        SAVEVALUE  13-,V6
300        SAVEVALUE  111,X22            CENTS/HR. FOR 1 TRCTR.--FUTURE REF.
301        TRANSFER   ,CNVFC             CONVEYING F.C. - HYLG. & W.A.SLG.
302 HRVST  TRANSFER   PICK,303,304
303        TRANSFER   ,HAYLG             HAYLAGE  40 - 50 % M.C. (W.B.)
304        TRANSFER   ,WASLG             WILTED ALF'A SILAGE 55-70%M.C.(W.B.)
305 HAYLG  LOGIC S    7                  SET MODE INDICATES HAYLAGE
306        MSAVEVALUE 1,1,F1,K43         NETWORK NODE NUMBER.
307        ASSIGN     1+,K1              NEXT COL. OF MX1 TO BE USED.
308        SAVEVALUE  10,XH47,H          M.C. OF HAYLAGE.
309        SAVEVALUE  29,XH13,H          HP.-HR./TON D.M.  X10
```

```
         TRANSFER    ,FHARV
WASLG    LOGIC R     7                   RESET MODE INDICATES WILTED ALF'A SLG
         MSAVEVALUE  1,1,F1,K44          NETWORK NODE NUMBER.
         ASSIGN      1+,K1               NEXT COL. OF MX1 TO BE USED.
         SAVEVALUE   29,XH12,H           HP.-HR./TON D.M.  X10
         SAVEVALUE   10,XH48,H           M.C. OF WILTED ALFALFA SILAGE.
FHARV    TRANSFER    PICK,317,319
         TRANSFER    ,CYLPU              CYLINDER TYPE WITH PICK-UP ATTACHMT.
         TRANSFER    ,FLYPU              FLYWHEEL TYPE WITH PICK-UP ATTACHMT.
         TRANSFER    ,SPFPU              SELF-PRO.TYPE WITH PICK-UP ATTACHMT.
CYLPU    MSAVEVALUE  1,1,P1,K61          NETWORK NODE NUMBER.
         ASSIGN      1+,K1               NEXT COL. OF MX1 TO BE USED.
         ASSIGN      11,K6
         SAVEVALUE   90,K2
         TRANSFER    SBR,RNGEN,10
         ASSIGN      11+,X90             CYL. TYPE WITH PICK-UP
         TRANSFER    ,FFF
FLYPU    MSAVEVALUE  1,1,P1,K62          NETWORK NODE NUMBER.
         ASSIGN      1+,K1               NEXT COL. OF MX1 TO BE USED.
         ASSIGN      11,K1
         SAVEVALUE   90,K4
         TRANSFER    SBR,RNGEN,10
         ASSIGN      11+,X90             FLY. TYPE WITH PICK-UP
FFF      SAVEVALUE   24,XH71             P.T.O. HP. ON P-T FRG. HARVESTER
         SAVEVALUE   13+,MH8(1,*11)      INITIAL COST OF 1 UNIT. $.
         SAVEVALUE   20,MH8(2,*11)       PER ANNUM FIXED COST. $.
         SAVEVALUE   22,MH8(3,*11)       REPAIR COST IN CENTS/HOUR.
         SAVEVALUE   6+,V100             UPDATE TOTAL P.A. MCH. & EQMT. COST
         SAVEVALUE   19,X22              TEMPORARY STORAGE OF REP. RATE.
         SAVEVALUE   49,X24              A NECESSARY DUMMY LABEL.
         TRANSFER    SBR,DTRCT,15
         SAVEVALUE   22+,X19             TOTAL REPAIR COST IN CENTS/HOUR.
         MSAVEVALUE  1,1,38,V100         P.A. F.C. OF TRACTOR ON FRG. HRVSTR.
```

```
343       TRANSFER    ,AAA
344 SPFPU MSAVEVALUE  1,1,P1,K63          NETWORK NODE NUMBER.
345       ASSIGN      1+,K1
346       ASSIGN      11,K38
347       SAVEVALUE   90,K1
348       TRANSFER    SBR,RNGEN,10
349       ASSIGN      11+,X90             SP TYPE WITH PICK-UP
350       SAVEVALUE   13+,MH7(1,*11)      INITIAL COST OF 1 UNIT. $.
351       SAVEVALUE   20,MH7(3,*11)       PER ANNUM FIXED COST.  $.
352       SAVEVALUE   22,MH7(4,*11)       REPAIR COST IN CENTS/HOUR.
353       SAVEVALUE   6+,V100             UPDATE TOTAL P.A. MCH. & EQMT. COST
354       SAVEVALUE   24,MH7(2,*11)       DIESEL PTO. HP.
355       TRANSFER    ,AAA
356 PRAT2 TRANSFER    PICK,357,358
357       TRANSFER    ,SFBLR              SILAGE - FORAGE BLOWER
358       TRANSFER    ,SFACC              SILAGE - FLIGHT-&-CHAIN CONVEYOR
359 SFBLR MSAVEVALUE  1,1,P1,K91          NETWORK NODE NUMBER.
360       ASSIGN      1+,K1               NEXT COL. OF MX1 TO BE USED.
    37    FVARIABLE   X31*XH70*300/XH77+1/2
361       TEST G      V37,X38,GGG
362       SAVEVALUE   38,V37              UPPER UNLOADING RATE
363 GGG   SAVEVALUE   39,V37              CONVEYING RATE
364       TRANSFER    ,SLGWD
365 SFACC LOGIC S     8                   SET MODE INDICATES F&C CONVEYOR
366       MSAVEVALUE  1,1,P1,K94          NETWORK NODE NUMBER.
367       ASSIGN      1+,K1               NEXT COL. OF MX1 TO BE USED.
368       SAVEVALUE   64,K75,H
369       SAVEVALUE   90,K50              RANGES FROM 75 - 125 F.P.M. F&C SPEED
370       TRANSFER    SBR,RNGEN,10
371       SAVEVALUE   64+,X90,H           F&C CONVEYOR SPEED IN F.P.M.
372       GATE LR     7,SFAC3             IF HAYLAGE, GO TO SFAC3.
373       TRANSFER    PICK,374,376
374       TRANSFER    ,SFAC1              WOOD STAVE SILO
```

```
375        TRANSFER    ,SFAC2             CONCRETE STAVE SILO.
376        TRANSFER    ,SFAC3             STEEL SILO.
377 SFAC1  SAVEVALUE   103,K1
378        MSAVEVALUE  1,1,P1,K101        NETWORK NODE NUMBER.
379        ASSIGN      1+,K1              NEXT COL. OF MX1 TO BE USED.
380        SAVEVALUE   90,K6              RANGE OF LIST NUMBERS
381        TRANSFER    ,SFAC4
382 SFAC2  SAVEVALUE   103,K8
383        MSAVEVALUE  1,1,P1,K102        NETWORK NODE NUMBER.
384        ASSIGN      1+,K1              NEXT COL. OF MX1 TO BE USED.
385        SAVEVALUE   90,K9
386        TRANSFER    ,SFAC4
387 SFAC3  SAVEVALUE   103,K18
388        MSAVEVALUE  1,1,P1,K103        NETWORK NODE NUMBER.
389        ASSIGN      1+,K1              NEXT COL. OF MX1 TO BE USED.
390        SAVEVALUE   90,K19
391 SFAC4  TRANSFER    SBR,RNGEN,10
392        SAVEVALUE   103+,X90
393        SAVEVALUE   100,FN20           LIST NO. OF SILO.
    38     FVARIABLE   X31*(100-XH10)*3000/(XH64*14*FN21/1000)+1/2
394        TEST G      V38,X38,NNN
395        SAVEVALUE   38,V38             UPPER UNLOADING RATE.
396 NNN    SAVEVALUE   39,V38             CONVEYING RATE
397        TRANSFER    ,SLGWD
   * FIND PER ANNUM FIXED COSTS OF BLOWER.
398 CNVFC  GATE LR     8,FCCNV            IF SET, GO TO F & C CONVEYOR.
399        GATE LR     4,HHH              DUMP UNIT INDICATED
400        TRANSFER    PICK,401,402
401        TRANSFER    ,FBSH              FRG. BLWR. - SHORT(AUGER) HOPPER
402 HHH    TRANSFER    ,FBLH              FRG. BLWR. - LONG(CONVEYOR) HOPPER
403 FBSH   MSAVEVALUE  1,1,P1,K92         NETWORK NODE NUMBER.
404        ASSIGN      1+,K1              NEXT COL. OF MX1 TO BE USED.
405        ASSIGN      11,K9
```

```
406         SAVEVALUE   90,K5
407         TRANSFER    SBR,RNGEN,10
408         ASSIGN      11+,X90            FRG. BLWR. WITH SHORT HOPPER
409         TRANSFER    ,III
410 FELH    MSAVEVALUE  1,1,P1,K93         NETWORK NODE NUMBER.
411         ASSIGN      1+,K1              NEXT COL. OF MX1 TO BE USED.
412         ASSIGN      11,K15
413         SAVEVALUE   90,K4
414         TRANSFER    SBR,RNGEN,10
415         ASSIGN      11+,X90            FRG. BLWR. WITH LONG  HOPPER
416 III     SAVEVALUE   13+,MH8(1,*11)     INITIAL COST OF 1 UNIT. $ .
417         SAVEVALUE   20,MH8(2,*11)      PER ANNUM FIXED COST.  $.
418         SAVEVALUE   22,MH8(3,*11)      REPAIR COST IN CENTS/HOUR.
419         SAVEVALUE   6+,V100            UPDATE TOTAL P.A. MCH. & EQMT. COST
420         SAVEVALUE   24,XH77            P.T.O. HP. ON FRG. BLWR.
421         TRANSFER    PICK,422,423
422         TRANSFER    ,FBPTO             FORAGE BLOWER - P.T.O. DRIVE
423         TRANSFER    ,FBELC             FORAGE BLOWER - ELECTRIC DRIVE
  * FIND PER ANNUM FIXED COST OF PTO. UNIT ON FORAGE BLOWER.
424 FBPTO   MSAVEVALUE  1,1,P1,K96         NETWORK NODE NUMBER.
425         ASSIGN      1+,K1              NEXT COL. OF MX1 TO BE USED.
426         GATE LS     20,HTRN5           IF CUSTOM RATES USED FOR TRANSPORT
  *                                        UNIT(S), USE SAME FOR BLOWER.
427         SAVEVALUE   49,X24             A NECESSARY DUMMY LABEL.
428         SAVEVALUE   19,X22             TEMPORARY STORAGE OF REP. RATE.
429         TRANSFER    SBR,CTRCT,15
430         SAVEVALUE   22+,X19            TOTAL REPAIR RATE IN CENTS/HOUR.
431         MSAVEVALUE  1,1,40,V100        P.A. F.C. OF TRACTOR ON FRG. BLOWER.
  * FIND P.A. OPERATING COST OF PTO. UNIT ON FRG. BLWR.
   39       FVARIABLE   X52*X38*(1000+XH38)/1000000+1/2
432         MSAVEVALUE  1,1,35,V39         OPERATING MIN. OF FORAGE BLOWER.
   40       FVARIABLE   V39*X24*XH66*XH23*115/(1000*1000)+V39*X22/60+1/2
433         SAVEVALUE   7+,V40             UPDATE TOTAL P.A. MCH. OPERATING COST
```

```
    * SINCE LAECUR ALREADY CALCULATED FOR THIS TASK,
434        TRANSFER   ,USILO             TOWER SILO STORAGE
435  HTRNS SAVEVALUE  19,K1              ONE UNIT.
436        SAVEVALUE  20,XH40            CENTS PER HOUR CHARGED.
     19    FVARIABLE  X19*X20/60+1/2
437        SAVEVALUE  7+,V19             UPDATE TOTAL P.A. MCH. OPERATING COST
438        TRANSFER   ,USILO             TOWER SILO STORAGE
    * FIND P.A. FIXED COST OF ELECTRIC UNIT ON FORAGE BLOWER.
439  FEELC SAVEVALUE  24,XH77            P.T.O. HP.
     41    FVARIABLE  X24*10*2/3+1/2
     42    FVARIABLE  V39*X101*7452*XH21/(100000*100)+V39*X22/60+1/2
440        MSAVEVALUE 1,1,P1,K97         NETWORK NODE NUMBER.
441        ASSIGN     1+,K1              NEXT COL. OF MX1 TO BE USED.
442        SAVEVALUE  101,V41            EQUIVALENT ELECTRIC HP.X10 .
    * FIND P.A. OPERATING COST OF ELECTRIC MOTOR ON FRG. BLOWER.
443        SAVEVALUE  7+,V42             UPDATE TOTAL MCH. & EQMT. OPN. COST
444        SAVEVALUE  13+,FN2            INITIAL COST OF 1 UNIT. $.
445        SAVEVALUE  20,FN2             INITIAL COST OF 1 UNIT. $.
446        SAVEVALUE  6+,V7              UPDATE TOTAL P.A. MCH. & EQMT. COST
    * SINCE LAECUR ALREADY CALCULATED FOR THIS TASK,
447        TRANSFER   ,USILO             TOWER SILO STORAGE
    * FIND PER ANNUM FIXED COST OF FLIGHT-&-CHAIN CONVEYOR USED FOR FORAGE
    * HANDLING.
448  FCCNV SAVEVALUE  13+,MH8(1,21)      UPDATE TOTAL MACH. LAYOUT.
449        SAVEVALUE  20,MH8(2,21)       F.A. FIXED COST $.
450        SAVEVALUE  22,MH8(3,21)       REPAIR RATE IN CENTS/HOUR.
451        SAVEVALUE  6+,V100            UPDATE TOTAL P.A. MACH. & EQMT. COST
     95    FVARIABLE  10*FN19/2
452        SAVEVALUE  20,V95             $I.C. OF X-CONVEYOR.
453        SAVEVALUE  13+,X20            UPDATE TOTAL MACH. LAYOUT.
454        SAVEVALUE  21,XH33            AMORT. RATE  %X10 .
455        SAVEVALUE  23,XH32            HOUSING RATE. %.
456        SAVEVALUE  20,V10             F.A.F.C.
```

```
457       SAVEVALUE  6+,V100              UPDATE TOTAL P.A. MCH. & EQMT. COST
  * FIND P.A. FIXED COST OF F&C CONVEYOR POWER SOURCE.
   43     FVARIABLE  2*XH65*FN27*3*5/10+1/2
   44     FVARIABLE  (X31*2000*50/X38)*((FN27+FN19/2)*FN12/100+FN15)*10
   45     FVARIABLE  X41*130/(33000*XH57)+1/2          EL. HP. X10
458       SAVEVALUE  41,V43
459       SAVEVALUE  41+,V44
460       TRANSFER   PICK,461,462
461       TRANSFER   ,GGG                 GASOLINE ENGINE - 2 CYCLE.
462       TRANSFER   ,PPP                 ELECTRIC MOTOR - 3-PHASE DRIP-PROOF.
463 GGG   SAVEVALUE  41,V45               ELECTRIC HP. X10 REQUIRED
464       MSAVEVALUE 1,1,P1,K98           NETWORK NODE NUMBER.
465       ASSIGN     1+,K1                NEXT COL. OF MX1 TO BE USED.
   46     FVARIABLE  X41*3/20+1/2
466       SAVEVALUE  102,V46              GAS. HP. 2 CYCLE (FULL HP.)
467       SAVEVALUE  13+,FN4              INITIAL COST OF 1 UNIT. $.
468       SAVEVALUE  20,FN4               INITIAL COST OF 1 UNIT. $.
469       SAVEVALUE  6+,V7                UPDATE TOTAL P.A. MCH. & EQMT. COST
  * FIND OPERATION COST OF GASOLINE ENGINE ON C&F CONVEYOR.
   47     FVARIABLE  V39*X102*XH65*XH22*115/(60000*1000)+V39*X22/60+1/2
470       SAVEVALUE  7+,V47               UPDATE TOTAL MACHINE OPERATION COST
471       TRANSFER   ,SILON               NUMBER OF SILOS REQUIRED
472 PPP   SAVEVALUE  41,V45               ELECTRIC HP. X10 REQUIRED
473       MSAVEVALUE 1,1,P1,K99           NETWORK NODE NUMBER.
474       ASSIGN     1+,K1                NEXT COL. OF MX1 TO BE USED.
  * CONVERT ELECTRIC HP. X10 TO NEAREST HALF ELECTRIC HP.
475       SAVEVALUE  101,X41
476       SAVEVALUE  101+,K5              ELECTRIC HP. X10
  * FIND OPERATION COST OF ELECTRIC MOTOR ON F&C CONVEYOR
477       SAVEVALUE  7+,V42               UPDATE TOTAL MACHINE OPERATION COST
478       SAVEVALUE  13+,FN2              INITIAL COST OF 1 UNIT. $.
479       SAVEVALUE  20,FN2               INITIAL COST OF 1 UNIT. $.
480       SAVEVALUE  6+,V7                UPDATE TOTAL P.A. MCH. & EQMT. COST
```

```
481        TRANSFER    ,SILCN              NUMBER OF SILOS REQUIRED                  1085
   * UPRIGHT SILOS --  CHOOSE TYPE AND SIZE.                                           1086
482 USILO  GATE LR     7,STEEL             IF IN SET MODE, HAYLAGE INDICATED.        1087
483 JJJ    TRANSFER    PICK,484,486        FOR WILTED ALFALFA SILAGE.                1088
484        TRANSFER    ,WDSTV              WOOD STAVE                                1089
485        TRANSFER    ,CNSTV              CONCRETE STAVE                            1090
486        TRANSFER    ,STEEL              STEEL HERM. SEALED                        1091
487 WDSTV  SAVEVALUE   90,K6                                                         1092
488        MSAVEVALUE  1,1,P1,K101         NETWORK NODE NUMBER.                      1093
489        ASSIGN      1+,K1               NEXT COL. OF MX1 TO BE USED.              1094
490        SAVEVALUE   100,K1                                                        1095
491        TRANSFER    SBR,RNGEN,10                                                  1096
492        SAVEVALUE   100+,X90            LIST NUMBER OF SILO.                      1097
493        TRANSFER    ,SILCN              NUMBER OF SILOS.                          1098
494 CNSTV  SAVEVALUE   90,K15                                                        1099
495        MSAVEVALUE  1,1,P1,K102         NETWORK NODE NUMBER.                      1100
496        ASSIGN      1+,K1               NEXT COL. OF MX1 TO BE USED.              1101
497        SAVEVALUE   100,K8                                                        1102
498        TRANSFER    SBR,RNGEN,10                                                  1103
499        SAVEVALUE   100+,X90            LIST NUMBER OF SILO.                      1104
500        TRANSFER    ,SILCN              NUMBER OF SILOS.                          1105
501 STEEL  SAVEVALUE   90,K34                                                        1106
502        MSAVEVALUE  1,1,P1,K103         NETWORK NODE NUMBER.                      1107
503        ASSIGN      1+,K1               NEXT COL. OF MX1 TO BE USED.              1108
504        SAVEVALUE   100,K24                                                       1109
505        TRANSFER    SBR,RNGEN,10                                                  1110
506        SAVEVALUE   100+,X90            LIST NUMBER OF SILO.                      1111
   * NUMBER OF SILOS REQUIRED.                                                       1112
    48     FVARIABLE   X57*(100-FN6)/100+1/2                                         1113
507 SILCN  SAVEVALUE   57,V48              T. D.M. STORED X10 .                      1114
    49     FVARIABLE   X57/(FN13*XH37)+1/2                                           1115
508        SAVEVALUE   19,V49              NUMBER OF SILOS REQUIRED.                 1116
509        GATE LR     8,KKK               IF SET MODE F&C CONVEYOR INDICATED.       1117
```

```
  * FIND P.A. F.C. OF BLWR. PIPING ASSUMING THAT EACH SILO IS SO EQUIPPED
510        SAVEVALUE  21,XH33           AMORT. RATE  % X10
    83     FVARIABLE  X19*FN15*350/100+1/2
511        SAVEVALUE  16+,V83           UPDATE TOTAL OUTLAY FOR STORAGE.
    50     FVARIABLE  X19*FN15*350*(X21/10+XH30+XH31/10)/100
512        SAVEVALUE  8+,V50            UPDATE TOTAL STORAGE COST.
  * FIND INVESTMENT IN STORAGE UNITS.
513        SAVEVALUE  36,FN14
514        SAVEVALUE  16+,V8            UPDATE TOTAL OUTLAY FOR STORAGE.
  * FIND P.A. COST OF STORAGE UNITS.
    90     FVARIABLE  FN16*X57/(FN13*XH37)+1/2
515 KKK    SAVEVALUE  8+,V90            UPDATE TOTAL P.A. STORAGE COST.
  * FIND UNLOADER COST.
516        TEST L     X100,K24,MMM      IF UNLDR. COST INCL'D. IN SILO COST,
  * TOP UNLOADER  $ INITIAL COST.
517        ASSIGN     11,K7
518        SAVEVALUE  18,FN19           SILO DIAMETER IN FEET.
  * TOTAL REPAIR RATE OF 25% ( DECKER-'60) IS IGNORED SINCE SOME SILO
  * COST DATA INCLUDE AN UNLOADER WHICH THEREFORE IS NOT GIVEN A REPAIR
  * RATE ON AN HOURLY BASIS.  USE 1.2 % = A REPAIR RATE FOR TOWER SILOS.
519        SAVEVALUE  21,MX2(7,14)      AMORT. RATE %X10.
    51     FVARIABLE  (MX2(7,10)+MX2(7,11)*X18)/100+1/2
520        SAVEVALUE  36,V51            COST PER UNLOADER.
521        SAVEVALUE  16+,V8            UPDATE OUTLAY FOR STORAGE FACILITIES.
    52     FVARIABLE  X19*V51*(X21/10+XH30+XH31/10+12/10)+1/2
522        SAVEVALUE  8+,V52            UPDATE TOTAL P. A. STORAGE COST.
  * FIND D. M. STORAGE LOSSES.
523 MMM    TEST G     X100,K55,QQQ      IF NOT HORIZ. SLD. STRG.,GO TO QQQ
524        SAVEVALUE  42,K3             3% EXTRA LOSS - SURFACE SPOILAGE
525 QQQ    ASSIGN     13,FN18
526        SAVEVALUE  42+,FN*13
  * ALTER SAVE-XH8 AND SAVE-XH9 TO WILTED SILAGE VALUES (NRC MODIFIED)
527        SAVEVALUE  118,K114          % DCP X10  100% D.M. BASIS
```

```
528         SAVEVALUE  119,K1111          KCAL./LB. OF DRY MATTER
   53       FVARIABLE  (X57-X120)*X42*(X118*X1+X119*X2*2)/(1000*1000)+1/2
529         SAVEVALUE  5+,V53             UPDATE TOTAL STORAGE LOSS
   * FIND TOTAL TONS OF W.M. TO UNLOAD.
   54       FVARIABLE  X57*(100-X42)/(100-XH10)+1/2
530         SAVEVALUE  43,V54             TOTAL TONS OF W.M. TO UNLOAD  X10
531         TEST G     X100,K55,RRR       IF NOT HORIZ. SLD. STRG.,GO TO RRR
   * FIND UNLOADING CAPACITY FOR HORIZONTAL SEALED STORAGE UNITS.
532         SAVEVALUE  60,K120,H          CAPACITY - ARBITRARY LOWER LIMIT
   * UPPER LIMIT TAKEN = MANUFACTURER'S CLAIM.
533         SAVEVALUE  90,K80             12 - 20 TONS W.M./HR. RANGE
534         TRANSFER   SBR,RNGEN,10
535         SAVEVALUE  60+,X90,H          SILO UNLOADER CAPACITY T.W.M./HR. X10
536 RRR     TRANSFER   PICK,537,538
537         TRANSFER   ,FDBCX             SOME TRANSPORT UNIT USED.
538         TRANSFER   ,BKFDR             FEED-BUNK CONVEYORS USED.
539 FDBCX   SAVEVALUE  13+,MH8(1,22)      ADD $I.C. OF 18' C-&-F CONVEYOR
540         MSAVEVALUE 1,1,P1,K110        NETWORK NODE NUMBER.
541         ASSIGN     1+,K1              NEXT COL. OF MX1 TO BE USED.
542         SAVEVALUE  20,MH8(2,22)       F.A. F.C. OF CONVEYOR.
543         SAVEVALUE  22,MH8(3,22)       REPAIR COST IN CENTS/HOUR.
544         SAVEVALUE  6+,V100            UPDATE TOTAL P.A. MACH. & EQMT. COST.
545         SAVEVALUE  49,K406            FT.**3/FLIGHT X1000
   * BASED ON A 45 DEGREE ELEV., A 40 DEGREE ANGLE OF REPOSE, AND A MAX.
   * FLIGHT VOLUME OF LEVEL-FULL.
   91       FVARIABLE  4*X49*XH64*36/(1400*(100-XH10))+1/2
546         TEST L     V91,XH60,SSS       IF C-&-F CONV. CAP. IS NOT LMTG., GO
547         SAVEVALUE  60,V91,H           RESET SILO UNLOADING RATE.
   92       FVARIABLE  2*XH64*12*3*5/10+1/2
   93       FVARIABLE  (X43*10/3)*(18*FN12/100+18)*10+1/2
548 SSS     SAVEVALUE  41,V92
549         SAVEVALUE  41+,V93
550         SAVEVALUE  101,V45            EL. HP. X10 REQUIRED.
```

```
   94    FVARIABLE  X43*7452*X101*XH21/(XH60*10000*100)+X43*X22/XH60+1/2
551      SAVEVALUE  10+,V94              UPDATE TOTAL DISTRIBUTION COST.
552      SAVEVALUE  13+,FN2              $I.C. OF ELECTRIC MOTOR.
553      SAVEVALUE  20,FN2               $I.C. OF ELECTRIC MOTOR.
554      SAVEVALUE  6+,V7                UPDATE TOTAL P.A. MACH. & EQMT. COST.
555      TRANSFER   ,TTT
556 BKFDR MSAVEVALUE 1,1,P1,K114         NETWORK NODE NUMBER.
557      ASSIGN     1+,K1                NEXT COL. OF MX1 TO BE USED.
  * FIND OPERATING COST OF SILO UNLOADER(S).
   55    FVARIABLE  X43*7452*XH21/(XH60*1000000)+1/2
558 TTT  SAVEVALUE  10+,V55              UPDATE TOTAL UNLDG. & DISTR. COST
559      SAVEVALUE  42,K0                ASSUME NO D.M. LOSS DUE TO MECH.HNDLG
   56    FVARIABLE  (100-X42)*X43*(100-XH10)/10000+1/2
560      SAVEVALUE  43,V56               TOTAL TONS D.M. FED X10 .
561      TRANSFER   ,SUMRY
  *
  *         --  PRE-CUT WEATHER SUBROUTINE  --
  *
562 SPCUT SAVEVALUE 81,K10               MAXIMUM WORKING HOURS PER DAY.
  * THIS FIGURE SHOULD POSSIBLY DIFFER FOR HAYLAGE AND W.G.SILAGE.
  * SHOULD BE ABLE AT A LATER STAGE TO ALTER THE NO. OF HOURS FOR SOME
  * PARTICULAR DAY  I.E. DIFFERENCE IN DESIRED M.C.
563      SAVEVALUE  86,XH15              ACRES LEFT TO DO.
564      SAVEVALUE  85,K0                INITIALIZE COUNTER.
565      SAVEVALUE  17,K0                TOTAL MATURITY LOSSES ACCUMULATOR.
  * IN AC.-% X1000 , IN TERMS OF 1% DROP IN FORAGE INTAKE PER DAY HARVEST
  * IS DELAYED BEYOND EARLY BLOOM STAGE.
566      SAVEVALUE  118,XH8              CURRENT D.C.P.  %X10 .
567      SAVEVALUE  119,XH9              CURRENT DIGESTIBLE ENERGY KCAL./LB.
  * FIND : LOADING TIME, MANOEUVERING TIME, TRAVEL TIME, HITCH-UNHITCH
  * TIME IN MINUTES/LOAD X100 .
   60    FVARIABLE  X31*(100-XH10)*300000/(X47*X28)+1/2
568      SAVEVALUE  46,V60               STD. LOADING TIME MIN./LOAD X100
```

```
    * DETERMINE WHETHER ANY DELAYS OCCUR FOR FORAGE HARVESTER AT THE MAX.
    * NUMBER OF TRANSPORT UNITS.
569 TRAN1 SAVEVALUE  40,K0             INITIALIZE.
     61   FVARIABLE  ((X35+X34+X38)/X89-(X46+X32))/100+1/2
570       TEST GE    V61,K0,TRAN2      IF NO DELAYS, GO TO TRAN2
    * WHERE DELAYS DO OCCUR, SET NO. OF TRANSPORT UNITS AT THE MAX.
571       SAVEVALUE  40,V61            DELAYS IN MINUTES/LOAD.
572       SAVEVALUE  81,X89,H          NUMBER OF TRANSPORT UNITS.
573       SAVEVALUE  81-,K1,H          NUMBER OF TRANSPORTING UNITS.
574       TRANSFER   ,PCUT3
    * CHECK TO SEE IF ANY DELAYS OCCUR FOR ONE TRANSPORTING UNIT.
     62   FVARIABLE  (X46+X32-(X35+X34+X38))/100+1/2
575 TRAN2 TEST GE    V62,K0,TRAN3
    * WHERE DELAYS DO OCCUR, SET NO. OF TRANSPORTING UNITS TO ONE.
576       SAVEVALUE  81,K1,H           ONE TRANSPORTING UNIT.
577       TRANSFER   ,PCUT3
    * FIND NUMBER OF TRANSPORTING UNITS REQUIRED IF NOT ONE OR THE MAX.
     63   FVARIABLE  (X35+X34+X38)/(X46+X32)+1
578 TRAN3 SAVEVALUE  81,V63,H          NUMBER OF TRANSPORTING UNITS.
579       TRANSFER   ,PCUT3
    * FIND TOTAL LOADS PER DAY AND ACRES PER DAY.
     64   FVARIABLE  X81*60/(X40+(X46+X32)/100)+1/2
580 PCUT3 SAVEVALUE  92,V64            LOADS PER DAY.
     65   FVARIABLE  X92*X31*(100-XH10)/(20*X47)+1/2
581       SAVEVALUE  93,V65            ACRES PER DAY.
    * WEATHER FUNCTIONS AND PENALTIES.
582       SAVEVALUE  83,RN4            RANDOM NUMBER TO START THE SEASON.
    * TEST FOR GOOD OR BAD START.
583       TEST G     X83,X79,GOOD      IF RN <=PG , A GOOD START.
584 BAD   LOGIC R    13
585       SAVEVALUE  84,FN*17          LENGTH OF BAD PERIOD IN DAYS
586       SAVEVALUE  85+,X84           TOTAL DAYS
587       TEST GE    X85,K44,BAD1      IF END OF PERIOD NOT REACHED.
```

```
588         SAVEVALUE  85,K44             SET AT MAX.
589         TRANSFER   ,LOSSH
   * THIS NUMBER OF DAYS WILL VARY FROM 40 - 44 DAYS AFTER CUTTING HAS
   * STARTED (ON THE AVERAGE).
   * CALCULATE MATURITY LOSSES.
590 EAD1    ADVANCE    X84
    67      FVARIABLE  X17+X84*X86*1000
591         SAVEVALUE  17,V67             NEW MATURITY LOSS AC.-% X1000 .
592 GOOD    LOGIC S    13
593         SAVEVALUE  84,FN*18           LENGTH OF GOOD PERIOD IN DAYS.
594         ASSIGN     2,X84              NO. OF DAYS IN GOOD PERIOD.
595         ASSIGN     2+,K1              REQUIRED FOR LOOP TEST.
596         ASSIGN     3,K1               DAYS USED IN GOOD PERIOD.
597         ADVANCE    1                  FIRST DAY IN GOOD PERIOD.
598         SAVEVALUE  85+,K1             TOTAL DAYS THIS CUTTING.
599 WLOOP   TEST G     X86,X93,HLOSS      IF ACRES LEFT < AC. POSSIBLE PER DAY.
    68      FVARIABLE  X17+1000*(X86-X93)
   * CALCULATE MATURITY LOSSES.
   * NOTE : MAT. LOSS ONLY SUMMED TO THE LAST GOOD DAY OF THE PERIOD.
600         SAVEVALUE  17,V68             NEW MATURITY LOSS FIGURE.
601         SAVEVALUE  86-,X93            FIND ACRES LEFT TO DO ON NEXT DAY.
602         ASSIGN     3+,K1
603         ADVANCE    1                  ADVANCE CLOCK ONE DAY.
604         SAVEVALUE  85+,K1             TOTAL DAYS THIS CUTTING.
605         TEST GE    X85,K44,GOOD1      IF END OF PERIOD NOT REACHED,
606         SAVEVALUE  85,K44             SET AT MAX.
607         TRANSFER   ,LOSSH
608 GOOD1   LOOP       2,599              IF END OF PERIOD NOT REACHED,
   *                                      GO TO WLOOP.
609         TRANSFER   ,EAD
610 HLOSS   SAVEVALUE  86,K0              ALL ACRES CUT.
    69      FVARIABLE  ((X17/1000)-X85*X86)*X47/100+1/2
611 LOSSH   SAVEVALUE  49,V69             EQUIV. MATURITY LOSS T.D.M. X10 .
```

```
   70     FVARIABLE  X49*(XH8*X1+XH9*X2*2)/10000+1/2
612       SAVEVALUE  3+,V70              MATURITY LOSSES IN CENTS.
613       SAVEVALUE  120+,X49            TOTAL T. DM.X10 EQUIV. LOSS .
  * FIND TOTAL DIGESTIBLE PROTEIN STORED.
   71     FVARIABLE  (XH15-(X86*(100-X85)/100))*X47*X118/5+1/2
614       SAVEVALUE  58+,V71             TOTAL D.P. STORED
  * NOTE: MATURITY FACTOR ONLY TEMPORARILY SET ASIDE.
  * FIND VALUE OF FEED LOST IF NOT CUT.
   72     FVARIABLE  X86*X47*(100-X85)*(XH8*X1+XH9*X2*2)/1000000+1/2
615       SAVEVALUE  15+,V72             CROP LOSSES IN CENTS.
  * FIND FIELD LOSSES.
   73     FVARIABLE  FN6*V71/(XH8*2)+1/2
   74     FVARIABLE  V73*(XH8*X1+XH9*X2*2)/100000+1/2
616 CCOST SAVEVALUE  4+,V74              FIELD LOSSES IN CENTS.
   75     FVARIABLE  (XH15-X86)*X47*(100-FN6)/100+1/2
617       SAVEVALUE  57+,V75             TOTAL TONS D.M.INTO STORAGE .
   76     FVARIABLE  V75*200/((100-XH10)*X31)+1/2
618       SAVEVALUE  52+,V76             TOTAL LOADS X10 .
   77     FVARIABLE  (X46+X32)*V76/1000+1/2
619       SAVEVALUE  49,V77              TEMPORARY STORAGE OF OPN. TIME (MIN.)
620       SAVEVALUE  55+,X49             OPERATING TIME OF FRG.HRVSTR.(MIN.)
   78     FVARIABLE  (X40+(X46+X32)/100)*V76/10+1/2
621       SAVEVALUE  53,V78              TOTAL TIME PER MAN(STD.MINUTES)
  * FIND THE MINUTES SPENT CUTTING.
   79     FVARIABLE  (XH15-X86)*60000/X107+1/2
622       SAVEVALUE  109+,V79             MINUTES CUTTING.
623       GATE LS    6,PCUT4             IF RAKING NOT IN THE SEQUENCE. GO TO
  * FIND THE MINUTES SPENT RAKING.
   80     FVARIABLE  (XH15-X86)*60000/X77+1/2
624       SAVEVALUE  110+,V80             MINUTES RAKING.
625 PCUT4 TRANSFER   P,K14,1
  *
  *            --  PRE-CUT EQUIPMENT SUBROUTINE --
```

```
    *
626 FCMCH TRANSFER   SBR,RNGEN,10
627       ASSIGN     11+,X90
628       SAVEVALUE  13+,MH7(1,*11)  INITIAL COST OF 1 UNIT. $ .
629       SAVEVALUE  20,MH7(3,*11)   PER ANNUM FIXED COST.  $.
630       SAVEVALUE  22+,MH7(4,*11)  REPAIR COST IN CENTS/HOUR.
631       SAVEVALUE  6+,V100         UPDATE TOTAL P.A. MCH. & EQMT. COST
632       TRANSFER   P,K15,1
    *
    *           --   INITIALIZING SUBROUTINE  --
    *
633 INITL SAVEVALUE  99,K14,H
634       SAVEVALUE  14,FN10,H
635       SAVEVALUE  99,K45,H
636 INIT  SAVEVALUE  99+,K1,H        INCREMENT SAVEXH NO. COUNTER
637       ASSIGN     9,XH99
638       SAVEVALUE  *9,K0,H         SET INITIALLY TO ZERO
639       TEST G     FN10,K0,INIT1   IF NO RANGE GIVEN, GO TO INIT1
640       SAVEVALUE  90,FN10
641       TRANSFER   SBR,RNGEN,10
642       SAVEVALUE  *9,X90,H
643 INIT1 SAVEVALUE  *9+,FN8,H
    * IF THE LAST NUMBER IN THE LIST HAS BEEN PROCESSED, ZERO THE FULL-WORD
    * SAVEVALUES.
644       TEST E     P9,K78,INIT
645 IZERO SAVEVALUE  99,K2,H         DO NOT ZERO SAVEX 1 OR 2.
646 IZER1 SAVEVALUE  99+,K1,H
647       ASSIGN     9,XH99
648       SAVEVALUE  *9,K0           ZERO FULL-WORD SAVEVALUE.
649       TEST E     XH99,K120,IZER1 IF SAVEX120 HAS NOT BEEN ZEROED, GO
    *                                TO IZER1 .
650       MSAVEVALUE 1,1,38,K0       ZERO MSAVEX(1,1,38-42)
651       MSAVEVALUE 1,1,39,K0
```

```
652          MSAVEVALUE 1,1,40,K0
653          MSAVEVALUE 1,1,41,K0
654          MSAVEVALUE 1,1,42,K0
655          MSAVEVALUE 1,1,43,K0
   * RESET SOME LOGIC SWITCHES.
656          LOGIC R     3
657          LOGIC R     4
658          LOGIC R     5
659          LOGIC R     6
660          LOGIC R     8
661          LOGIC R     11
662          TRANSFER    P,K15,1
   *
   *              --  WIDTH DEPENDENT CAPACITY SUBROUTINE  --
   *
663 RATE1  SAVEVALUE   28,K0              DUMMY
    14     FVARIABLE   MH3(*16,4)*X25*10/(1000+XH38)+1/2
   * THE COLUMN NO. CAN BE CHANGED IF NECESSARY.
664          SAVEVALUE   28,V14             AC./HR. X1000 INCLUDING %R.A.
665          TRANSFER    P,K15,1
   *
   *              --  POWER DEPENDENT CAPACITY SUBROUTINE  --
   *
666 RATE2  SAVEVALUE   28,K0              DUMMY
    15     FVARIABLE   X24*X27*1000000/(XH29*X47*(1000+XH38))+1/2
667          SAVEVALUE   28,V15             AC./HR. X1000 INCLUDING %R.A.
668          TRANSFER    P,K15,1
   *
   *              --  TRACTOR COST SUBROUTINE  --
   *
669 CTRCT  ASSIGN      7,K6               ROW 6 : DIESEL TRACTORS.
670          TRANSFER    ,TRCTR
671 CTRCT  ASSIGN      7,K5               ROW 5 : GASOLINE TRACTORS.
```

```
672 TRCTR SAVEVALUE  13+,V6            $COST = (A + BX)/100
673       SAVEVALUE  20,V6
  16      FVARIABLE  X20*MX2(*7,15)/100
674       SAVEVALUE  22,V16            REPAIR RATE IN CENTS/HOUR.
675       SAVEVALUE  20,V7             DOLLARS PER ANNUM FIXED COST.
676       TRANSFER   P,K15,1
    *
    *           --  TRANSIT SPEEDS SUBROUTINE  --
    *
677 SPEED SAVEVALUE  83,MH6(*11,1),H MIN.
678       SAVEVALUE  90,MH6(*11,2)   MAX.
679       SAVEVALUE  90-,XH83          RANGE
680       TRANSFER   SBR,RNGEN,10
681       SAVEVALUE  83+,X90,H         ROAD SPEED LOADED M.P.H. X10
682       SAVEVALUE  84,MH6(*11,4),H MIN.
683       SAVEVALUE  90,MH6(*11,5)   MAX.
684       SAVEVALUE  90-,XH84          RANGE
685       TRANSFER   SBR,RNGEN,10
686       SAVEVALUE  84+,X90,H         ROAD SPEED EMPTY  M.P.H. X10
687       TRANSFER   P,K15,1
    *
    *           --  RNGEN SUBROUTINE  --
    *
    * GPSS SUBROUTINE TO PICK A POINT AT RANDOM FROM A VALUE SPECIFIED IN
    * THE MAINLINE, ROUNDING OFF INSTEAD OF TRUNCATING THE VALUE CHOSEN.
688 RNGEN SAVEVALUE  89,RN1,H          RANDOM NUMBER
  11      FVARIABLE  X90*(XH89+1)/1000+1/2
    * THE ' 1/2 ' INSURES THAT THE FIRST TRUNCATED DIGIT>=5 CAUSES THE NEXT
    * LARGEST INTEGER NUMBER TO BE CHOSEN.
689       SAVEVALUE  99,V11            TEMPORARY STORAGE.
    * MAKE SURE THAT THE RANGE IS NOT EXCEEDED.
690       TEST LE    X99,X90,RNEND
691       SAVEVALUE  90,X99            CHOSEN VALUE
```

```
692 RNEND TRANSFER   P,K10,1
    *
    *        ---  SUMMARY   -----
    *
693 SUMRY MSAVEVALUE 1,1,P1,K1000      FINAL NETWORK NODE NUMBER.
694       MSAVEVALUE 1,1,1,N4          TRANSACTION NUMBER
695       MSAVEVALLE 1,1,17,X6         F.A. F.C. CF EGUIPMENT CTHER THAN
    *                                  TRACTORS, TRUCKS, AND WAGCNS.
696       MSAVEVALUE 1,1,18,X31        GROSS T. W.M./LCAD X2 .
697       MSAVEVALLE 1-,1,18,K2        LESS 1 TON FCR BOX.
698       MSAVEVALUE 1,1,19,X120       EFFECTIVE MATURITY LOSS IN T. D.M.X10
699       MSAVEVALUE 1,1,20,X57        TCNS OF D.M. X10 STCRED.
700       MSAVEVALUE 1,1,21,X43        TONS OF D.M. X10 FED .
701       MSAVEVALUE 1,1,22,X58        LB. OF D.P. STORED.
      96  FVARIABLE  X43*((X57-X120)/X57)*X118/5+1/2
702       MSAVEVALUE 1,1,23,V96        LB. OF D.P. FED.
703       MSAVEVALLE 1,1,24,XH90       MAXIMUM NUMBER CF MEN (1).
704       MSAVEVALUE 1,1,25,XH91       MAXIMUM NUMBER CF MEN (2).
705       MSAVEVALUE 1,1,32,X55        TCTAL OPERATING MIN. OF HRVSTR.
706       MSAVEVALLE 1,1,33,X109       TCTAL OPERATING MIN. OF CUTTING UNIT.
707       MSAVEVALUE 1,1,34,X110       TOTAL OPERATING MIN. OF RAKING UNIT.
708       MSAVEVALUE 1,1,44,X13        TOTAL OUTLAY ($) FOR MCH. & EQMT.
709       MSAVEVALUE 1,1,45,X16        TOTAL OUTLAY FOR STCRAGE FACILITIES.
710       MSAVEVALLE 1,1,46,X6         TTL. P.A.F.C. OF MCH. LESS TRNSPRTS.
    *                                  AND LESS TRACTCRS CR TRUCKS.
711       MSAVEVALLE 1,1,47,X7         TOTAL P.A. MCH. & EQMT. CPERN.COST.
712       MSAVEVALUE 1,1,48,X8         TOTAL P.A. STORAGE COST.
713       MSAVEVALLE 1,1,49,X9         TCTAL P.A. LABCUR COST.
714       MSAVEVALLE 1,1,50,X10        TCTAL P.A. DISTRIBUTION COST.
715       MSAVEVALLE 1,1,51,X3         MATURITY AND/OR WEATHER LOSSES.
716       MSAVEVALLE 1,1,52,X4         FIELD LCSSES.
717       MSAVEVALLE 1,1,53,X5         STORAGE LOSSES.
718       MSAVEVALLE 1,1,54,X15        LCSSES DUE TO UNHARVESTED ACRES.
```

```
719          MSAVEVALUE 1,1,55,XH81      MAX. NUMBER OF TRANSPORTING UNITS.
720          MSAVEVALUE 1,1,56,X50       NO. OF TRACTORS PACKING &/OR UNLDG.
   * IF S.P. HARVESTER USED, GO TO SUM1.
721          TEST G     MX1(1,38),K0,SUM1
722          SAVEVALUE  19,MX1(1,32)     TIME IN MINUTES.
723          SAVEVALUE  20,MX1(1,38)     PER ANNUM FIXED COST.
    97       FVARIABLE  X19*X20/(XH19*60)+1/2
724          MSAVEVALUE 1+,1,46,V97      TOTAL P.A. F.C. OF MCH. & EQMT.
   * IF NO TRACTOR USED FOR CUTTING OR RAKING, GO TO SUM2
725 SUM1     TEST G     MX1(1,39),K0,SUM2
726          SAVEVALUE  19,MX1(1,33)     TIME IN MINUTES.
727          SAVEVALUE  19+,MX1(1,34)    TIME IN MINUTES.
728          SAVEVALUE  20,MX1(1,39)     PER ANNUM FIXED COST.
729          MSAVEVALUE 1+,1,46,V97      TOTAL P.A. F.C. OF MCH. & EQMT.
   * IF NO P.T.O. POWER USED ON FORAGE BLOWER, GO TO SUM3.
730 SUM2     TEST G     MX1(1,40),K0,SUM3
731          GATE LS    20,SUM3          IF CUSTOM UNIT USED, GO TO SUM3.
732          SAVEVALUE  19,MX1(1,35)     TIME IN MINUTES.
733          SAVEVALUE  20,MX1(1,40)     PER ANNUM FIXED COST.
734          MSAVEVALUE 1+,1,46,V97      TOTAL P.A. F.C. OF MCH. & EQMT.
    98       FVARIABLE  X19*X20/(XH81*XH19*60)+1/2
   * IF CUSTOM CHARGES USED INSTEAD OF P.A.F.C. OF TRACTOR AND TRUCK
   * TRANSPORT(S), GO TO SUM4.
735 SUM3     TEST G     MX1(1,42),K0,SUM4
736          GATE LS    20,SUM4          IF CUSTOM UNIT USED, GO TO SUM4.
737          SAVEVALUE  19,MX1(1,37)     TIME IN MINUTES.
738          SAVEVALUE  20,MX1(1,42)     PER ANNUM FIXED COST.
739          MSAVEVALUE 1+,1,46,V98      TOTAL P.A. F.C. OF MCH. & EQMT.
740 SUM4     MSAVEVALUE 1+,1,46,X43      ADD CUSTOM CHARGES.
741 SUM7     MSAVEVALUE 1+,1,46,X14      ADD P.A.F.C. OF WAGON(S) USED.
742          MSAVEVALUE 1,1,57,MX1(1,46) TOTAL PER ANNUM COST.
743          ASSIGN     8,K46
744          ASSIGN     2,K8
```

```
745 SLOOP ASSIGN     8+,K1              INCREMENT VECTOR COORDINATE.
746       MSAVEVALUE 1+,1,57,MX1(1,*8)
         LOOP        2,745
    99    FVARIABLE  (X118*X1/(X118*X1+X119*X2*2))*MX1(1,57)*20/MX1(1,23)
747       MSAVEVALUE 1,1,58,V99         TOTAL COST PER TON D.P. FED ($)
748       PRINT      1,1,MX,1
   * TERMINATE THE YEAR.
749 TERM  SAVEVALUE  100,K365,H         DAYS IN THE YEAR.
750       SAVEVALUE  100-,M1,H
751       ADVANCE    XH100              TERMINATE THE YEAR.
          LIST
752       TERMINATE  1
          START      2000
          END
```

APPENDIX I

LIST OF THE GPSS VARIABLES

I1. General Notes on the GPSS Variables

The equations used in the GPSS programs were purposely restricted to the FVARIABLE type. These variables require integer inputs but calculate in floating-point before truncating the answer to an integer value. For the purposes of this simulation, the increased accuracy helped to minimize the cumulated truncation error. In addition, the '1/2' found at the end of most of the variable definition cards was included to round the answers to their nearest whole numbers. As in the FORTRAN language, multiplication and division take precedence over addition and subtraction.

In the explanation following each listed variable, some shorter notation may have been used for the following items:

Digestible protein of the cheapest protein source (dp_p)

Digestible protein of the cheapest energy source (dp_e)

Kilocalories of digestible energy (kcal)

Kilotherms of digestible energy (kth)

Tons of wet matter (twm)

Tons of dry matter (tdm)

Tons of digestible protein (tdp)

Moisture content, wet basis (mc)

Power take-off (pto hp)

I2. GPSS Variables for High Moisture Silage and Dehydrated Alfalfa

V1 = XH1-(XH2*XH5/XH4)*2000/XH3+1/2

For an organic portein source, cost of purchased protein in cents per ton of digestible protein

$$= \frac{¢}{\text{T cheapest protein source}} - \frac{¢}{\text{bu cheapest energy source}}$$

$$\times \frac{\%dp_e \times 10}{\%dp_p \times 10} \times \frac{2000\ \text{lb}}{\text{T}} \div \frac{\text{lb}}{\text{bu}}$$

V2 = XH1*1000/XH4+1/2

For urea, cost of purchased protein in cents per ton of digestible protein $= \frac{¢}{\text{T cheapest protein source (urea)}}$

$$\times \frac{1000\%}{\%dp_p \times 10}$$

V3 = (1000000*XH2/XH3-XH5*X1/2)/XH7+1/2

Cost of purchased energy in cents per kilotherm of digestible energy

$$= \left(\frac{¢}{\text{bu cheapest energy source}} \div \frac{\text{lb}}{\text{bu}} - \frac{\%dp_e \times 10}{1000\%}\right.$$

$$\left.\times \frac{¢}{\text{tdp}} \div \frac{2000\ \text{lb}}{\text{T}}\right) \div \left(\frac{\text{kcal}}{\text{lb}_e} \times \frac{1\ \text{kth}}{10^6\ \text{kcal}}\right)$$

V4 = (MX2(*8,10)+MX2(*8,11)*(X31+2)*10*(100-XH10)/X35)/100

Initial cost in dollars per transport unit

$$= \left(\frac{¢}{\text{unit}} + \frac{¢/\text{ft}^3}{\text{unit}} \times \frac{\frac{\text{twm}}{\text{load}} \times 2 + \frac{1\text{T}}{\text{box}} \times 2}{2} \times \frac{2000\ \text{lb}}{\text{T}}\right.$$

$$\left.\times \frac{(100\% - \text{mc}\%)\text{dm}}{100\%\ \text{wm}} \div \frac{\text{lb dm}}{\text{ft}^3}\right) \div \frac{100¢}{\$}$$

V5 = (MX2(*8,10)+MX2(*8,11)*(X31+2)/2)/100+1/2

Initial cost in dollars per transport unit

$$= \left(\frac{¢}{\text{unit}} + \frac{¢/\text{T}}{\text{unit}} \times \frac{\frac{\text{twm}}{\text{load}} \times 2 + \frac{1\text{T}}{\text{box}} \times 2}{2}\right) \div \frac{100¢}{\$}$$

V6 = (MX2(*7,10)+X49*MX2(*7,11)/100+1/2

Initial cost in dollars per tractor

$$= \left(\frac{¢}{\text{tractor}} + \frac{¢}{\text{pto hp}} \times \frac{\text{pto hp}}{\text{tractor}}\right) \div \frac{100¢}{\$}$$

V7 = X20*(XH34/10+XH30+XH31/10+XH32)/100+1/2

$$= \frac{\$\ \text{initial cost}}{\text{tractor}} \times (\text{amortization}\ \% \times \frac{10}{10} + \text{interest}\ \%$$

$$+ \text{insurance}\ \% \times \frac{10}{10} + \text{housing}\ \%)/100\%$$

V8 = X19*X36

$$\$\ \text{cost} - \text{units} \times \frac{\$\ \text{costs}}{\text{unit}}$$

V9 = X19*X36(X21/10+XH30+XH31/10+XH32)+1/2

Per annum fixed cost in cents

$$= \text{units} \times \frac{\$\ \text{initial cost}}{\text{unit}} \times \frac{100¢}{\$} \times (\text{amortization}\ \% \times \frac{10}{10}$$

$$+ \text{interest}\ \% + \text{insurance}\ \% \times \frac{10}{10} + \text{housing}\ \%)/100\%$$

V10 = X20*(21/10+XH30+XH31/10+X23)+1/2

Per annum fixed cost in cents

$$= \$\ \text{initial cost} \times \frac{100¢}{\$} \times (\text{amortization}\ \% \times \frac{10}{10} + \text{interest}$$

$$+ \text{insurance}\ \% \times \frac{10}{10} + \text{housing}\ \%)/100\%$$

V11 = X90*(XH89+1)/1000+1/2

$$\text{Randomly chosen number} = \text{value} \times \frac{\text{3 digit random number} + 1}{1000}$$

V13 = X20*(100-XH14)/100+1/2

$$\text{Cost \$} = \text{cost \$} \times \frac{100\% - \%\ \text{salvage value}}{100\%}$$

V14 = MX3(*16,4)*X25*10/(1000+XH38)+1/2

$$\text{Standard capacity in } \frac{\text{ac}}{\text{hr}} \times 1000$$

$$= \frac{\text{ac}}{\text{hr-ft}} \times 1000 \times \text{ft} \times \frac{100}{100} \times \frac{1000\%}{1000\% + \text{rest allowance } \% \times 10}$$

V15 = X24*X27*1000000/(XH29*X478(1000+XH38)+1/2

$$\text{Standard capacity in } \frac{\text{ac}}{\text{hr}} \times 1000$$

$$= \text{pto hp} \times \frac{\text{field efficiency } \%}{100\%} \div \left(\frac{\text{pto hp - hr}}{\text{tdm}} \times \frac{10}{10}\right.$$

$$\left.\times \frac{\text{tdm}}{\text{ac}} \times \frac{10}{10}\right) \times \left(\frac{1000\%}{1000\% + \text{rest allowance } \% \times 10}\right) \times 1000$$

V16 = X20*MX2(*7,15)/100

$$\text{Repair rate in cents per hour} = \text{\$ list price} \times \frac{\%\ \text{of list price}}{100\ \text{hr operation}}$$

$$\times \frac{100¢}{\$} \times \frac{1}{100\%}$$

V20 = X33*X31/2+1/2

$$\text{Unloading time in } \frac{\text{minutes}}{\text{load}} \times 100 = \frac{\text{min}}{\text{twm}} \times \frac{100}{100}$$

$$\times \frac{\text{twm}}{\text{load}} \times \frac{2}{2}$$

V21 = (X51*MX1(1,28)+X54*MX1(1,29))*X20*X81

If units are hired on a day rate, custom charges for transport trucks or tractors in cents

= (transporting units (1st cut) x days to harvest (1st cut)

+ transporting units (2nd cut) x days to harvest (2nd cut))

$$\times \text{custom charges in } \frac{¢}{\text{hr}} \times \frac{\text{hr}}{\text{day}}$$

V22 = X19*X20/60+1/2

Custom unloading cost in cents = unloading time in min

$x \frac{¢}{hr} \div \frac{60 \text{ min}}{hr}$

V25 = X34*(1000+XH38(/1000+1/2

Standard manoeuvering time in $\frac{min}{load}$ x 100

$= \text{manoeuvering time } \frac{min}{load} \times 100 \times \frac{1000\% + \text{rest allowance } \% \times 10}{1000}$

V26 = X38*(1000+XH38)/1000+1/2

Standard unloading time $\frac{min}{load}$ x 100

V27 = XH17*10*(1/XH83+1/XH84)*6000+1/2

Standard travelling time in $\frac{min}{load}$ x 100

$= \frac{\text{miles one way}}{load} \times 10 \times \left(\frac{1}{\text{mph} \times 10 \text{ empty}} + \frac{1}{\text{mph} \times 10 \text{ loaded}}\right)$

$\times \frac{60 \text{ min}}{hr} \times 100$

V28 = X32*(1000+XH39)/100+1/2

Standard hitching-unhitching time $\frac{min}{load}$ x 100

V29 = XH80*X53XH20/60+1/2

Labour cost in cents

$= \text{no. of men} \times \frac{min}{man} \times \frac{¢}{\text{man-hr}} \times \frac{1 \text{ hr}}{60 \text{ min}}$

V32 = X55*X24*X29*X30*115/(60000*1000)+X55*X22/60+1/2

Operating cost in cents of forage harvester (fuel, oil, lubrication and repairs)

$= \text{min} \times \text{pto hp} \times \frac{gal}{\text{pto hp - hr}} \times \frac{1000}{1000} \times \frac{¢}{gal} \times \frac{10}{10}$

$\times \frac{115}{100} \times \frac{1 \text{ hr}}{60 \text{ min}} + \text{min} \times \text{repair cost in } \frac{¢}{hr} \times \frac{1 \text{ hr}}{60 \text{ min}}$

V33 = X52*(X32+X34+X35+X38)/1000+1/2

Total operating minutes of transport units

$= \text{loads} \times \frac{10}{10} \times (\text{hitching-unhitching} + \text{manoeuvering} + \text{travelling} + \text{unloading time}) \frac{\text{min}}{\text{load}} \times \frac{100}{100}$

V34 = XH76*XH65*XH22*V33*115/(60000*1000)

Operating cost unit in cents (fuel, oil and lubrication) of transport

$= \text{pto hp} \times \frac{\text{gal}}{\text{pto hp - hr}} \times \frac{1000}{1000} \times \frac{¢}{\text{gal}} \times \frac{10}{10} \times \text{min} \times \frac{115}{100} \times \frac{1 \text{ hr}}{60 \text{ min}}$

V35 = ((X34+X32)/6000+XH17*10/XH84)*XH84/XH69+1/2

V36 = (V35+(X38/6000+XH17*10/XH83)*XH83/XH68)*X52*XH22/100

Operating cost in cents (fuel only) of truck transport units

$= \{[(\text{hitching-unhitching} + \text{manoeuvering}) \frac{\text{min}}{\text{load}} \times \frac{100}{100} \times \frac{1 \text{ hr}}{60 \text{ min}} + \frac{\text{miles one way}}{\text{load}} \times \frac{10}{\text{mph} \times 10 \text{ empty}}] \times \frac{\text{mph} \times 10 \text{ empty}}{\text{mpg} \times 10 \text{ empty}}$

$+ [\text{unloading} \frac{\text{min}}{\text{load}} \times \frac{100}{100} = \frac{1 \text{ hr}}{60 \text{ min}} + \frac{\text{miles one way}}{\text{load}} \times \frac{10}{\text{mph} \times 10 \text{ loaded}}] \times \frac{\text{mph} \times 10 \text{ loaded}}{\text{mpg} \times 10 \text{ loaded}}\}$

$\times \text{loads} \times \frac{10}{10} \times \frac{¢}{\text{gal}} \times \frac{10}{10}$

V37 = X52*X39*(1000+XH38)/1000000+1/2

Total minutes spent in packing $= \text{loads} \times \frac{10}{10} \times \text{packing time in} \frac{\text{min}}{\text{load}} \times \frac{100}{100} \times \frac{1000\% + \text{rest allowance } \% \times 10}{1000\%}$

V38 = V37*XH76*XH65*XH22*115/(10000*60000)+1/2

Operating cost in cents of packing units

$$= \text{min} \times \text{pto hp} \times \frac{\text{gal}}{\text{pto hp - hr}} \times \frac{1000}{1000} \times \frac{¢}{\text{gal}} \times \frac{10}{10}$$

$$\times \frac{115}{100} \times \frac{1\ \text{hr}}{60\ \text{min}}$$

V39 = X57*2000000/(FN30*35*(100-XH10)*XH37)+1/2

Horizontal silo length required in ft x 10

$$= \text{tdm stored} \times 10 \times \frac{2000\ \text{lb}}{\text{T}} \times \frac{100\%\ \text{wm}}{(100\% - \text{mc}\%)\ \text{dm}}$$

$$\div \left(\frac{\text{ft}^3}{\text{lin ft silo}} \times \frac{35\ \text{lb}}{\text{ft}^3} \times \frac{\text{fillings}}{\text{year}} \times \frac{10}{10}\right)$$

V40 = FN28*XH85/1000+1/2

Outlay in dollars for storage facilities

$$= \frac{¢}{\text{lin ft silo}} \times \text{lin ft silo} \times \frac{10}{10} \times \frac{1\$}{100¢}$$

V41 = FN28*XH85*(X21/10+XH30+XH31/10+X22/10)/1000

$$\text{Per annum storage cost in cents} = \frac{\text{cents}}{\text{lin ft of silo}}$$

$$\times \text{lin ft of silo} \times \frac{10}{10} \times (\text{amortization } \% \times \frac{10}{10}$$

$$+ \text{interest } \% + \text{insurance } \% \times \frac{10}{10} + \text{repairs } \% \times \frac{10}{10})/100\%$$

V42 = XH85*FN29/10+1/2

Per annum cost in cents of plastic covering

$$= \text{lin ft silo} \times \frac{10}{10} \times \frac{¢}{\text{lin ft silo}}$$

V43 = (X57-X120)*FN11*(X118*X1+119*X2*2)/(1000*1000)+1/2

$$\text{Storage losses in cents} = (\text{tdm stored} \times \frac{10}{10} -$$

$$\text{equivalent maturity loss tdm} \times \frac{10}{10}) \times \frac{\%\text{dm storage loss}}{100\%\ \text{dm}}$$

$$\times \left[\frac{\%\text{dp} \times 10}{1000\%\ \text{dm}} \times \frac{¢}{\text{tdp}} + \frac{\text{kcal}}{\text{lb dm}} \times \frac{¢}{\text{kth}} \times \frac{1\text{kth}}{10^6\text{kcal}} \times \frac{2000\ \text{lb}}{\text{T}}\right]$$

V44 = X57*(100-FN11)/(100-XH10)+1/2

Total twm to unload x 10 = tdm stored x 10 x

$$\frac{100\% - \%\ \text{storage loss}}{100\%} \times \frac{100\%\ \text{wm}}{(100\% - \text{mc}\ \%)\ \text{dm}}$$

V45 = X42*(X43*(100-XH10)/100-X120)/100+1/2

$$\text{Trampling loss in tdm} \times 10 = \frac{\%\ \text{dm loss}}{100\%\ \text{dm}}$$

$$\times\ (\text{twm to unload} \times 10 \times \frac{(100\% - \text{mc}\ \%)\ \text{dm}}{100\%\ \text{wm}}$$

- equivalent maturity loss tdm x 10)

V46 = V45*(X118*X1+X119*X2*2)/10000+1/2

$$\text{Trampling loss in cents} = \text{loss in tdm} \times \frac{10}{10} \times$$

$$\left(\frac{\%\ \text{dp} \times 10}{1000\%\ \text{dm}} \times \frac{¢}{\text{tdp}} + \frac{\text{kcal}}{\text{lb dm}} \times \frac{¢}{\text{kth}} \times \frac{1\ \text{kth}}{10^6\ \text{kcal}} \times \frac{2000\ \text{lb}}{\text{T}}\right)$$

V47 = X20*FN31*15/2000+1/2

Cost in dollars of self-feeding gate

$$= \frac{\$\ \text{initial cost}}{20\ \text{ft}} \times \text{ft width of silo} \times \frac{10}{10} \times \frac{100\% + 50\%\ \text{for labour cost}}{100\%}$$

V48 = V47*(X21/10XH30+XH31/10+X22/10)+1/2

Per annum fixed cost in cents of self-feeding gate

$$= \$\ \text{cost} \times \frac{100¢}{\$} \times (\text{amortization}\ \% \times \frac{10}{10} + \text{interest}\ \%$$

$$+ \text{insurance}\ \% \times \frac{10}{10} + \text{repairs}\ \% \times \frac{10}{10})/100\%$$

V49 = XH20*FN31+XH85*(1000+XH39)/(20*1000*60)+1/2

Labour cost in cents of moving self-feeder

$$= \frac{¢}{\text{man-hr}} \times \text{ft width} \times \text{silo length ft} \times \frac{10}{10} \times$$

$$\frac{1000\% + \text{rest allowance}\ \%}{100\%} \times \frac{1\ \text{hr}}{60\ \text{min}} \times \frac{10\ \text{man-min}}{20\ \text{ft}}$$

V50 = 60*X43*(10000+XH38)/(1000*X49)+1/2

Minutes spent unloading

$$= \frac{60 \text{ min}}{\text{hr}} \times \text{twm} \times \frac{10}{10} \times \frac{1000\% + \text{rest allowance } \% \times 10}{1000\%}$$

$$\div \left(\frac{\text{twm}}{\text{hr}} \times \frac{10}{10}\right)$$

V51 = XH76*XH65*XH22*V50*115/(10000*6000)+V50*X111/60+1/2

Operating cost in cents of mechanically unloading the silo

$$= \text{pto hp} \times \frac{\text{gal}}{\text{pto hp - hr}} \times \frac{1000}{1000} \times \frac{¢}{\text{gal}} \times \frac{10}{10} \times \text{min}$$

$$\times \frac{1 \text{ hr}}{60 \text{ min}} \times \frac{115}{100} + \text{min} \times \text{repair rate in } \frac{¢}{\text{hr}} \times \frac{1 \text{ hr}}{60 \text{ min}}$$

V52 = XH20*V50/60+1/2

Labour cost in cents of unloading the silo $= \frac{¢}{\text{man-hr}}$

$$\times \text{man-min} \times \frac{1 \text{ hr}}{60 \text{ min}}$$

V53 = (100-X42)*X43*(100-XH10)/10000+1/2

$$\text{Total tdm fed} \times 10 = \frac{100\% - \% \text{ feeding loss}}{100\%} \times$$

$$\text{twm unloaded} \times \frac{10}{10} \times \frac{(100\% - \text{mc } \%) \text{ dm}}{100\% \text{ wm}}$$

V54 = X31*10*(XH10-10)*(100/XH46)/3+1/2

Maximum dehydration rate in $\frac{\text{min}}{\text{load}} \times 100$

$$= \frac{\text{twm}}{\text{load}} \times \frac{2}{2} \times \frac{(\text{mc } \% - 10\%) \text{ water removed}}{100\% \text{ wm}} \times \frac{2000 \text{ lb}}{\text{T}}$$

$$\times \frac{1 \text{ hr}}{18000 \text{ lb water}} \times \frac{100\%}{\text{efficiency } \%} \times \frac{60 \text{ min}}{\text{hr}} \times 100$$

Note: Manufacturer's rated capacity of this unit is 18,000 lb water per hour when initial moisture content of the material is greater than or equal to 70% (wb) and the machine is uniformly fed. Efficiency ranges from 50-80%, according to Fortin (20). Some maximum figures

are: oil consumption of 180 gph, apron capacity of 800 ft^3 and feeder rate of 2375 ft^3/hr. Dehydration calculations are based on a dehydrated moisture content of 10% (wb) although equilibrium moisture content usually ranges from 5 to 8% (according to Richey (104)).

V55 = X31*(100-XH10)*60000/(X35*2375)+1/2

Maximum feeder rate in $\frac{\text{min}}{\text{load}} \times 100 = \frac{\text{twm}}{\text{load}} \times \frac{2}{2}$

$\times \frac{(100\% - \text{mc }\%)\text{ dm}}{100\%\text{ wm}} \times \frac{2000\text{ lb}}{\text{T}} \times \frac{60\text{ min}}{\text{hr}} \times 100$

$\div (\frac{\text{lb dm}}{\text{ft}^3} \times \frac{2375\text{ ft}^3}{\text{hr}})$

V56 = X52*X39*(1000+XH38)*122/(60000*1000)+1/2

hp-hr of electric motors on dehydrator unit

$= \text{loads} \times \frac{10}{10} \times \text{max. dehyd. rate } \frac{\text{min}}{\text{load}} \times \frac{100}{100}$

$\times \frac{1000\% + \%\text{ rest allowance} \times 10}{1000\%} \times 122\text{ hp} \times \frac{1\text{ hr}}{60\text{ min}}$

V57 = V56*7452*XH21/1000000+1/2

Operating cost of electric motors on dehydrator unit

$= \text{hp - hr} \times \frac{7252\text{ kw}}{10000\text{ hp}} \times \frac{¢}{\text{kwh}} \times \frac{100}{100}$

V58 = X52*X31*(XH10-10)*180*175*(100/XH46)/180000+1/2

Operating cost of oil furnace on dehydration unit

$= \text{loads} \times \frac{10}{10} \times \frac{\text{twm}}{\text{load}} \times \frac{2}{2} \times \frac{(\text{mc }\% - 10\%)\text{ water}}{100\%\text{ wm}} \times \frac{2000\text{ lb}}{\text{T}}$

$\times \frac{180\text{ gal}}{18000\text{ lb water}} \times \frac{¢}{\text{gal fuel oil}} \times \frac{10}{10} \times \frac{100\%}{\text{efficiency }\%}$

V60 = MH3(*16,X80)*X25*10/(1000+XH38)+1/2

Standard capacity in $\frac{ac}{hr}$ x 1000 = $\frac{ac}{hr\text{-}ft}$ x 1000

x ft width x $\frac{100}{100}$ x $\left(\frac{100\%}{1000\% + \text{rest allowance } \% \times 10}\right)$

V61 = X31*(100-XH10)*300000/(X47*X28)+1/2

Standard loading time in $\frac{min}{load}$ x 100 = $\frac{twm}{load}$ x $\frac{2}{2}$

x $\frac{(100\% - mc\ \%)\ dm}{100\%\ wm}$ x $\frac{60\ min}{hr}$ x 100 ÷ $\left(\frac{tdm}{ac} \times \frac{10}{10} \times \frac{ac}{hr} \times \frac{1000}{1000}\right)$

V62 = ((X35+X34+X38)/X89-(X46+X32))/100+1/2

Delays in minutes per load for the forage harvester when the maximum number of transporting units is utilized

$= \left[\frac{(\text{travelling} + \text{manoeuvering} + \text{unloading})\ \frac{min}{load} \times 100}{\text{no. of transporting units}}\right.$

$\left. - (\text{loading} - \text{hitching} - \text{unhitching})\frac{min}{load} \times 100\right] \div 100$

V63 = (X46+X32-(X35+X34+X38))/100+1/2

Delays for one transporting unit in minutes per load

= (loading + hitching = unhitching - (travelling + manoeuvering + unloading))$\frac{min}{load}$ x $\frac{100}{100}$

V64 = (X35+X34+X38)/(X46+X32)+1

The number of transporting units required if not one or the maximum = $\frac{\text{travelling + manoeuvering + unloading time}}{\text{loading + hitching - unhitching time}}$

V65 = X81*60/(X40+(X46+X32)/100)+1/2

Loads per day = $\frac{hr}{day}$ x $\frac{60\ min}{hr}$ ÷ (delays in $\frac{min}{load}$ + (loading + hitching - unhitching)$\frac{min}{load}$ x $\frac{100}{100}$

V66 = X92*X31*(100-XH10)/(20*X47)+1/2

$$\text{Acres per day} = \frac{\text{loads}}{\text{day}} \times \frac{\text{twm}}{\text{load}} \times \frac{2}{2} \times \left(\frac{100\% - \text{mc }\%)\text{ dm}}{100\%\text{ wm}}\right.$$

$$\div \left(\frac{\text{tdm}}{\text{ac}} \times \frac{10}{10}\right)$$

V67 = X17+X84*X86*1000

New maturity loss in ac-% x 1000 for bad weather periods

$$= \text{old ac-}\% \times 1000 + \text{days} \times \text{ac left} \times \frac{1\%}{\text{day}} \times 1000$$

V68 = X17+1000*(X86-X93)

New maturity loss in ac-% x 100 for a good day

$$= \text{old ac-}\% \times 100 + 1000 \times \frac{1\%}{\text{day}} \times 1\text{ day} \times (\text{ac left} - \text{ac}$$

possible that day)

V69 = ((X17/1000)-X85*X86)*X47/100+1/2

Equivalent maturity loss in tdm x 10 for acres harvested

$$\text{only} = (\text{total ac-}\% \times \frac{1000}{1000} - \text{days} \times \frac{1\%}{\text{day}} \times \text{acres left})$$

$$\times \frac{\text{tdm}}{\text{ac}} \times 10 \times \frac{1}{100\%}$$

V70 = X49*(XH8*X1+XH9*X2*2)/10000+1/2

$$\text{Maturity loss in cents} = \text{tdm loss} \times \frac{10}{10}$$

$$= \left(\frac{\%\text{ dp} \times 10}{1000\%\text{ dm}} \times \frac{¢}{\text{tdp}} + \frac{\text{kcal}}{\text{lb dm}} \times \frac{¢}{\text{kth}} \times \frac{1\text{ kth}}{10^6\text{kcal}} \times \frac{2000\text{ lb}}{\text{T}}\right)$$

V71 = (XH15-(X86*(100-X85)/100))*X47*X118/5+1/2

Total digestible protein stored in lb

$$= (\text{acres} - (\text{acres unharvested} \times \frac{100\% - \%\text{ maturity loss}}{100\%}))$$

$$\times \frac{\text{tdm}}{\text{ac}} \times \frac{10}{10} \times \frac{\%\text{ dp} \times 10}{1000\%} \times \frac{2000\text{ lb}}{\text{T}}$$

V72 = X86*X47*(100-X85)*(XH8*X1+H9*X2X@)/1000000+1/2

Losses in cents due to unharvested material

$$= \text{ac left} \times \frac{\text{tdm}}{\text{ac}} \times \frac{10}{10} \times \left(\frac{100\% - \%\ \text{maturity loss}}{100\%}\right)$$

$$\times \left(\frac{\%\ \text{dp} \times 10}{1000\%\ \text{dm}} \times \frac{¢}{\text{tdp}} + \frac{\text{kcal}}{\text{lb}} \times \frac{¢}{\text{kth}} \times \frac{1\ \text{kth}}{10^6\text{kcal}} \times \frac{2000\ \text{lb}}{\text{T}}\right)$$

V73 = FN6*V71/(XH8*2)+1/2

$$\text{Field loss in tdm} \times 100 = \frac{\%\ \text{field loss}}{100\%} \times \text{lb dp stored}$$

$$\times 100 \div \left(\text{original } \frac{\%\ \text{dp} \times 10}{1000\%\ \text{dm}} \times \frac{2000\ \text{lb}}{\text{T}}\right)$$

V74 = V73*(XH8*X1+XH9*X2*2)/100000+1/2

$$\text{Field losses in cents} = \text{loss in tdm} \times \frac{10}{10}$$

$$\times \left(\frac{\%\ \text{dp} \times 10}{1000\%} \times \frac{¢}{\text{tdp}} + \frac{\text{kcal}}{\text{lb}} \times \frac{¢}{\text{kth}} \times \frac{1\ \text{kth}}{10^6\text{kcal}} \times \frac{2000\ \text{lb}}{\text{T}}\right.$$

V75 = (XH15+X86)*X47*(100-FN6)/100+1/2

$$\text{tdm stored} \times 10 = (\text{total acres} - \text{acres left})$$

$$\times \frac{\text{tdm}}{\text{ac}} \times \frac{10}{10} \times \frac{100\% - \text{field loss}\ \%}{100\%}$$

V76 = V75*200/((100-XH10)*X31)+1/2

$$\text{Total loads} \times 10 = \text{tdm stored} \times 10$$

$$\times \frac{100\%\ \text{wm}}{(100\% - \text{mc}\ \%)\ \text{dm}} \div \left(\frac{\text{twm}}{\text{load}} \times \frac{2}{2}\right)$$

V77 = (X46-X32)*V76/1000+1/2

Operating time in minutes of forage harvester

$$= (\text{loading} + \text{hitching} - \text{unhitching})\frac{\text{min}}{\text{load}} \times \frac{100}{100} \times \text{loads} \times \frac{10}{10}$$

V78 = (X40+(X46+X32)/100)*V76/10+1/2

Standard minutes per man

$$= \left(\text{delays min} + \text{loading cycle } \frac{\text{min}}{\text{load}} \times \frac{100}{100}\right) \times \text{loads} \times \frac{10}{10}$$

V81 = X52*(x32+X34+X38)/100+1/2

V82 = V81+X52*XH17*10*60*(1/XH84+1/XH83)+1/2

Total operating minutes of truck transport units

$$= \text{loads} \times (\text{hitching - unhitching + manoeuvering + unloading})\frac{\text{min}}{\text{load}}$$

$$\times \frac{100}{100} + \text{loads} \times \frac{\text{miles one way}}{\text{load}} \times \frac{60\ \text{min}}{\text{hr}} \times \left(\frac{10}{\text{mph} \times 10\ \text{empty}}\right.$$

$$\left.+ \frac{10}{\text{mph} \times 10\ \text{loaded}}\right)$$

V83 = X19*X20/100+1/2

$$\text{Initial cost in dollars} = \text{ft}^2\ \text{area} \times \frac{¢}{\text{ft}^2} \times \frac{1\$}{100¢}$$

V84 = X20*(X21/10+XH30+1+X22)+1/2

Per annum fixed cost in cents

$$= \$\ \text{initial cost} \times \frac{100¢}{\$} \times (\text{amortization}\ \% \times \frac{10}{10} + \text{interest}\ \%$$

$$+ 1\%\ \text{insurance} + \%\ \text{repairs})/100\%$$

V85 = X57*10000/((100-XH10)*224)+1/2

Building length required in lin ft x 10

$$= \text{tdm stored} \times \frac{10}{10} \times \frac{100\%\ \text{wm}}{(100\% - \text{mc}\ \%)\ \text{dm}} \times \frac{100\ \text{lin ft}}{224\ \text{twm}} \times 10$$

V86 = X19*XH85*X20/1000+1/2

$$\$\ \text{cost} = \text{width in ft} \times \text{length in ft} \times \frac{10}{10} \times \frac{¢}{\text{ft}^2} \times \frac{1\$}{100¢}$$

V88 = 2*XH64*XH85*3*5/10+1/2

V89 = (X31*XH10*100000/(XH49*X39))*(XH85*55/100+15)*10+1/2

V90 = X41*130/(33000*XH57)+1/2

$$\text{Electric hp} \times 10 = \frac{2vL_cW_cF_c \times 10 + Q(L_hF_m+H)\times 10}{33000}$$

$$\times \frac{13}{10} \times \frac{100\%}{\text{efficiency}\ \%}$$

as used in the Materials Handling Manual (24), where

v = speed of conveyor (fpm)

L_c = horizontal projected length of conveyor (ft)

W_c = weight of flights and chain (lb/ft)

F_c = coefficient of friction for chains and flights

Q = quantity of material to be handled (lb/min)

L_h = horizontal projected length of loaded conveyor (ft)

H = height of lift (ft)

F_m = coefficient of friction for material being conveyed

E = motor efficiency (60-80%)

10% added for friction loss, 10% added for loss in reduction gearing, and 10% added for surges.

V91 = X57*(100+XH10)/100+1/2

Total dehydrated alfalfa into storage, twm x 10

$$= \text{tdm} \times 10 \times \frac{(100\% + \text{mc }\%)\ \text{wm}}{100\%\ \text{dm}}$$

V92 = X39*X52*(1000+XH38)/60000+1/2

V93 = (V92*X101*XH21/1000000)*7452/10000+1/2

Operating cost in cents of chain & flight elevator

$$= \frac{\text{min}}{\text{load}} \times \frac{100}{100} \times \text{loads} \times \frac{10}{10} \times \frac{1000\% + \text{rest allowance }\% \times 10}{1000\%}$$

$$\times \frac{1\ \text{hr}}{60\ \text{min}} \times \text{hp} \times \frac{10}{10} \times \frac{\text{¢}}{\text{kwh}} \times \frac{100}{100} \times \frac{7452\ \text{kw}}{10000\ \text{hp}}$$

V94 = X90*(100-XH49)*210+6/(800*135)+1/2

Dehydrated alfalfa unloading rate in $\frac{\text{twm}}{\text{hr}} \times 10$

$$= \frac{\text{twm}}{\text{hr}} \times 10 \times \frac{\text{ft}^3}{8\ \text{lb dm}} \times \frac{(100\% - \text{mc }\%)\ \text{dm}}{100\%\ \text{wm}} \times \frac{210}{135} \times \frac{6\ \text{lb. wm}}{\text{ft}^3}$$

Since the volume of a regular 60" manure bucket is approximately 1/2 yd^3 and this bucket holds more than 1/2 yd^3 of high moisture silage during horizontal-silo unloading, and since the loading time for a

scoop-full of chopped hay will be less than for a bucket-full of silage, let the horizontal silo unloading rate be converted to ft^3/hr and multiplied by the volume ratio to become the approximate loading rate for dehydrated alfalfa forage. Choosing a low density for chopped hay (6 lb/ft^3 used by Neubauer & Walker (93)) compensates somewhat for the possibility of longer, flail-cut forage.

V96 = X43*((X57-X120)/X57)*X118/5+1/2

Total dp fed in lb (carrying over the maturity loss figures)

$$= \text{tdm fed} \times \frac{10}{10} \times \frac{\text{tdm} \times 10 \text{ stored} - \text{tdm} \times 10 \text{ maturity loss}}{\text{tdm} \times 10 \text{ stored}}$$

$$\times \frac{\text{dp \%} \times 10}{1000\% \text{ dm}} \times \frac{2000 \text{ lb}}{\text{T}}$$

V97 = X19*X20/(XH19*60)+1/2

Per annum fixed cost in cents of power unit attributable to the forage enterprise

$$= \text{min} \times \text{total annual fixed cost ¢} \div \left(\frac{\text{hr}}{\text{yr}} \times \frac{60 \text{ min}}{\text{hr}}\right)$$

V98 = X19*X20/(*XH19*60)+1/2

Per annum fixed cost in cents of tractor(s) on transport or packing units attributable to the forage enterprise

$$= \text{min} \times \text{total annual fixed cost ¢} \div \left(\text{tractors} \times \frac{\text{hr}}{\text{tractor-yr}}\right.$$

$$\left.\times \frac{60 \text{ min}}{\text{hr}}\right)$$

V99 = (X118*X1/(X118*X1+X119*X2+2))*MX1(1,57)*20/MX1(1,23)

Cost in dollars per ton of digestible protein fed

$$= \frac{\text{value of dp per unit weight}}{\text{total value per unit weight}} \times \frac{\text{¢ total annual cost} \times \frac{1\$}{100¢}}{\text{lb dp fed} \times \frac{1\text{T}}{2000 \text{ lb}}}$$

V100 = X20*(100-XH14)

$$\text{Cost ¢} = \$ \text{ cost} \times \frac{100\% - \% \text{ salvage value}}{100\%} \times \frac{100¢}{1\$}$$

V101 = X22*V8/100+1/2

Repair rate in cents per hour = repair rate in $\frac{\text{\% of list}}{\text{100 hr}}$

x \$ cost x $\frac{100¢}{1\$}$ x $\frac{1}{100\%}$

V102 = MX1(1,37)*X111/(XH81*60)+1/2

Repair costs in cents for transport units = min. x total

repair rate in $\frac{¢}{\text{hr}}$ ÷ (units x $\frac{\text{60 min}}{\text{hr}}$)

V103 = MX1(1,36)*X111/(X19*60)+1/2

Repair costs for packing units in cents = min. x total

repair rate in $\frac{¢}{\text{hr}}$ ÷ (units x $\frac{\text{60 min}}{\text{hr}}$)

I3. GPSS Variables for Wilted Grass Silage and Haylage

V1 to V16 are the same as given in section 1.2.

V18 = (X51*MX1(1,28)+X54*MX1(1,29))*X20*X81

Custom charges in cents for transport trucks or tractors, assuming units are hired on a day rate

= (transporting units (1st cut) x days to harvest (1st cut)

+ transporting units (2nd cut) x days to harvest (2nd cut))

x custom charges in $\frac{¢}{\text{hr}}$ x $\frac{\text{hr}}{\text{day}}$

V19 = X19*X20/60+1/2

Custom unloading cost in cents = unloading time in

min. x $\frac{¢}{\text{hr}}$ x $\frac{\text{1 hr}}{\text{60 min}}$

V20 = is the same as given in section I.2.

V21 = MH3(2,1)*MH7(2,*11)*10/(1000+XH38)+1/2

Raking capacity in standard $\frac{\text{ac}}{\text{hr}}$ x 1000

= $\frac{\text{ac}}{\text{hr-ft}}$ x 1000 x width in ft x $\frac{100}{100}$ x $\frac{1000\%}{(1000\% + \text{rest allowance \% x } 10)}$

V22 = XH73*XH65*XH22*115/1000000+MH7(4,*11)+1/2

Operating cost of tractor on rake in cents per hour

$$= \text{pto hp} \times \frac{\text{gal}}{\text{pto hp-hr}} \times \frac{1000}{1000} \times \frac{¢}{\text{gal}} \times \frac{10}{10} \times \frac{115}{100}$$

$$+ \text{rake repair cost in} \frac{¢}{\text{hr}}$$

V23 = MH3(*16,1)*X105*10/(1000+XH38)+1/2

Cutting capacity in standard $\frac{\text{ac}}{\text{hr}} \times 1000$

$$= \frac{\text{ac}}{\text{hr-ft}} \times 1000 \times \text{width in ft} \times \frac{100}{100} \times \frac{1000\%}{(1000\% + \text{rest allowance } \% \times 10)}$$

V24 = X106*XH65*XH22*115/1000000+X22+1/2

Operating cost of tractor on mower in cents per hour

$$= \text{pto hp} \times \frac{\text{gal}}{\text{pto hp-hr}} \times \frac{1000}{1000} \times \frac{¢}{\text{gal}} \times \frac{10}{10} \times \frac{115}{100}$$

$$+ \text{mower repair cost } \frac{¢}{\text{hr}}$$

V25 to V29 are the same as given in section I.2.

V30 = X109*X108/60+1/2

Operating cost in cents of cutting unit $= \text{min} \times \frac{¢}{\text{hr}} \times \frac{1 \text{ hr}}{60 \text{ min}}$

V32 to V36 are the same as given in section I.2.

V37 = X31*XH70*300/XH77+1/2

Maximum forage blower capacity in $\frac{\text{min}}{\text{load}} \times 100$

$$= \frac{\text{twm}}{\text{load}} \times \frac{2}{2} \times \frac{(100\% - \text{mc}\%) \text{ dm}}{100\% \text{ wm}} \times \frac{2000 \text{ lb}}{\text{T}} \times 100$$

$$\div \left(\frac{4 \text{ lb dm}}{\text{ft}^3} \times \frac{\text{lin. ft}}{\text{min}} \times \frac{14 \text{ flights}}{12 \text{ lin. ft}} \times \frac{\text{ft}^3}{\text{flight}} \times \frac{1000}{1000}\right)$$

High moisture silage at a 2 foot settled depth has been observed to have a density of about 4.2 lb dm/ft^3(96). Therefore, 4 lb dm/ft^3 is used here as an approximation.

V39 = X52*X38*(1000+XH38)/1000000+1/2

Operating minutes of forage blower

$= \text{loads} \times \frac{10}{10} \times \text{unloading} \frac{\text{min}}{\text{load}} \times \frac{100}{100} \times$ (1000% + rest allowance

$\times \frac{(1000\% + \text{rest allowance } \% \times 10)}{1000\%}$

V40 = V39*X24*XH66*X23*115/(60000*1000)+V39*X22/60+1/2

Operating cost in cents of tractor on forage blower

$= \text{min} \times \text{pto hp} \times \frac{\text{gal}}{\text{pto hp-hr}} \times \frac{1000}{1000} \times \frac{¢}{\text{gal}} \times \frac{10}{10} \times \frac{115}{100}$

$\times \frac{1 \text{ hr}}{60 \text{ min}} + \text{min} \times \text{repair cost} \frac{¢}{\text{hr}} \times \frac{1 \text{ hr}}{60 \text{ min}}$

V41 = X24*10*2/3+1/2

Equivalent electric hp x 10 = pto hp x $\frac{2 \text{ electric}}{3 \text{ internal combustion}}$

V42 = V39*X101*7452*XH21/(100000*100)+1/2

Operating cost in cents of electric motor on forage blower

$= \text{min} \times \text{electric hp} \times \frac{10}{10} \times \frac{7452 \text{ kw}}{10000 \text{ hp}} \times \frac{¢}{\text{kwh}} \times \frac{100}{100}$

V43 = 2*XH65*FN27*3*5/10+1/2

V44 = (X31*2000*50/X38)*((FN27+FN19/2)*FN12/100*FN15)*10

V45 = X41*130/(33000*XH57)+1/2

See V88 to V90 in section I.2 for an explanation.

V46 = X41*3/20+1/2

Equivalent gasoline engine hp = electric hp x $\frac{10}{10}$

$\times \frac{3 \text{ gasoline engine hp}}{2 \text{ electric motor hp}}$

V47 = V39*X102*XH65*XH22*115/(60000*1000)+1/2

Operating costs in cents of gasoline engine on chain-&-flight conveyor

$= \text{min} \times \text{hp} \times \frac{\text{gal}}{\text{hp-hr}} \times \frac{1000}{1000} \times \frac{¢}{\text{gal}} \times \frac{10}{10} \times \frac{115}{100} \times \frac{1 \text{ hr}}{60 \text{ min}}$

V48 = X57*(100-FN6)/100+1/2

tdm stored x 10 - tdm harvested x 10

- (100% - field loss %)/100%

V49 = X57/(FN13*XH37)+1/2

Number of silos required = tdm stored x 10

$\div \left(\frac{\text{tdm}}{\text{silo filling}} \times \frac{\text{silo fillings}}{\text{year}} \times 10\right)$

V50 = X19*FN15*350*(X21/10+XH30+XH31/10)/100

Cost in cents of blower pipe = silos x $\frac{\text{feet of blower pipe}}{\text{silo}}$

$\times \frac{350¢}{\text{foot of blower pipe}} \times$ (amortization % $\times \frac{10}{10}$ + interest %

+ insurance % $\times \frac{10}{10}$)/100%

V51 = (MX2(7,10)+MX2(7,11)*X18/100+1/2

Cost per unloader in dollars = (cost $\frac{¢}{\text{unit}} + \frac{¢/\text{ft}}{\text{unit}}$

x silo diameter in ft) $\times \frac{1¢}{100¢}$

V52 = X19*V51*(X21/10+XH30+XH31/10+12/10)+1/2

Per annum storage cost in cents

= unloaders $\times \frac{\$}{\text{unloader}} \times \frac{100¢}{1\$} \times$ (amortization % $\times \frac{10}{10}$

+ interest % + insurance % $\times \frac{10}{10}$ + repairs % $\times \frac{10}{10}$)/100%

V53 = (X57-X120)*X42*(X118*X1+X119*X2*2)/1000000+1/2

Storage loss in cents = $\frac{\text{tdm stored x 10 - maturity loss tdm x 10}}{10}$

$\times \frac{\text{\% storage loss}}{\text{100\% dm}} \times \left(\frac{\text{dp \% x 10}}{1000\%} \times \frac{¢}{\text{tdp}} + \frac{\text{kcal}}{\text{lb}} \times \frac{¢}{\text{kth}}\right.$

$\left. \times \frac{1 \text{ kth}}{10^6 \text{kcal}} \times \frac{2000 \text{ lb}}{\text{T}}\right)$

V54 = X57*(100-X42)/(100-XH10)+1/2

twm to unload x 10 = tdm stored x 10

$$\times \frac{100\% - \%\text{ storage loss}}{100\%} \times \frac{100\%\text{ wm}}{(100\% - \text{mc }\%)\text{ dm}}$$

V55 = X43*7452*XH21/(XH60*1000000)+1/2

Operating cost in cents of silo unloader(s)

$$= \text{twm to unload} \times 10 \times \frac{7452\text{ kw}}{10000\text{ hp}} \times \frac{¢}{\text{kwh}}$$

$$\times \frac{100}{100} \div \left(\frac{\text{twm}}{\text{hr}} \times 10\right)$$

V56 = (100-X42)*X43*(100-XH10)/10000+1/2

$$\text{tdm fed} \times 10 = \frac{100\% - \%\text{ storage loss}}{100\%} \times \text{twm to unload}$$

$$\times 10 \times \frac{(100\% - \text{mc }\%)\text{dm}}{100\%\text{ wm}}$$

V60 = X31*(100-XH10)*30000/(X47*X28)+1/2

Standard loading time in $\frac{\text{min}}{\text{load}} \times 100$

$$= \frac{\text{twm}}{\text{load}} \times \frac{2}{2} \times \frac{(100\% - \text{mc }\%)\text{dm}}{100\%\text{ wm}} \times \frac{60\text{ min}}{\text{hr}}$$

$$\div \left(\frac{\text{tdm}}{\text{ac}} \times \frac{10}{10} \times \frac{\text{ac}}{\text{hr}} \times \frac{1000}{1000}\right)$$

V61 is the same as V62 in section I.2.

V62 is the same as V63 in section I.2.

V63 is the same as V64 in section I.2.

V64 is the same as V65 in section I.2.

V65 is the same as V66 in section I.2.

V67 to V78 are the same as given in section I.2.

V79 = (XH15-X86)*60000/X107+1/2

Minutes cutting = (total ac - unharvested ac) x $\frac{60\text{ min}}{\text{hr}}$

$\div (\frac{\text{ac}}{\text{hr}} \times \frac{1000}{1000})$

V80 = (XH15-X86)*60000/X77+1/2

Minutes raking = (total ac - unharvested ac) x $\frac{60\text{ min}}{\text{hr}}$

$\div (\frac{\text{ac}}{\text{hr}} \times \frac{1000}{1000})$

V81 and V82 are the same as given in section I.2.

V83 = X19*FN15*350/100+1/2

Cost in dollars of blower pipe = silos x $\frac{\text{ft of pipe}}{\text{silo}}$

$\times \frac{350¢}{\text{ft}} \times \frac{1\$}{100¢}$

V90 = FN16*X57/(FN13*XH37)+1/2

Per annum fixed cost in cents of storage facilities

$= \text{p.a.f.c.} \frac{¢}{\text{silo}} \times \text{tdm stored} \times 10 \div (\frac{\text{tdm}}{\text{silo filling}}$

$\times \frac{\text{fillings}}{\text{year}} \times 10)$

V91 = 4*X49*XH64*36/(1400*(100-XH10))+1/2

Chain & flight conveyor capacity in $\frac{\text{twm}}{\text{hr}} \times 10$

$= \frac{4\text{ lb dm}}{\text{ft}^3} \times \frac{\text{ft}^3}{\text{flight}} \times \frac{1000}{1000} \times \frac{\text{lin. ft}}{\text{min}} \times \frac{12\text{ flights}}{14\text{ lin. ft}}$

$\times \frac{60\text{ min}}{\text{hr}} \times \frac{1\text{T}}{2000\text{ lb}} \times \frac{100\%\text{ mw}}{(100\% - \text{mc }\%)\text{dm}} \times 10$

V92 and V93 are similar to V88 and V89 described in section I.2.

V94 = X43*7452*X101*XH21/(XH60*10000*100)+X43*X22/XH60+1/2

Operating cost in cents of electric motor on chain-&-flight conveyor

$$= \text{twm to unload} \times \frac{10}{10} \times \frac{7452 \text{ kw}}{10000 \text{ hp}} \times \text{hp} \times \frac{10}{10} \times \frac{¢}{\text{kwh}}$$

$$\times \frac{100}{100} \div \left(\frac{\text{twm}}{\text{hr}} \times \frac{10}{10}\right) + \text{twm to unload} \times \frac{10}{10} \times$$

$$\text{repair cost in } \frac{¢}{\text{hr}} \div \left(\frac{\text{twm}}{\text{hr}} \times \frac{10}{10}\right)$$

V96 to V102 are the same as given in section I.2.

APPENDIX J

CONSIDERATIONS OF ALTERNATIVE METHODS AND MACHINERY

J1. Alternative Forms of Forage

Although not all forms of forage were compared in this cost-benefit simulation, the following table summarizes some of the factors to be taken into acocunt when attempting to pinpoint the optimum system. The following table is not all-inclusive but does cover most items of concern. References to articles by Hundtoft (61), Hundtoft and Guest (62) and Zimmerman (128-132) were made to underline the fact that many of these considerations are not peculiar to the Edmonton area.

J2. Alternative Types of Equipment

Table J2 summarizes many of the pros and cons relating to particular types of forage handling equipment. These items of machinery are used as components in procedures mentioned in Table J1, but have not necessarily been used in the two programs run in this cost-benefit analysis. Note that some of the points labelled "considerations" may not be disadvantageous in a particular farming situation but will prove to be limiting factors in the average one.

TABLE J1. EVALUATION OF ALTERNATIVE FORAGE FEEDSTUFFS

Form of Forage	Advantages	Considerations
Green chop[ab]	1. Fresh material for each day 2. Material can be fed mechanically or self-fed 3. Most intensive pasturing	1. Daily job regardless of weather 2. Failure to harvest entire crop at its maximum feeding value per acre
High-moisture silage[ab]	1. No curing period required 2. Can be fed mechanically or self-fed directly from storage	1. Low palatability 2. Considerable seepage loss and mess 3. Faster silo deterioration 4. Silage freezing 5. Odour
Wilted silage[ab]	1. Can be fed mechanically 2. Limited weather risk 3. Less objectionable odour	1. Short chopping required to prevent knitting of feed and consequent unloading difficulties
Haylage[ab]	1. Can be fed mechanically 2. Less moisture handled 3. Reduced freezing problem 4. May provide adequate protein 5. More palatable than hay 6. Potentially low total loss	1. Critical emphasis on management unless a high-cost sealed storage unit is used 2. Greater power requirements for chopping and for filling silo 3. Rapid dulling of chopper knives 4. Periodical removal of gum residues from equipment is required 5. Higher field losses and extended weather risk 6. Roof required on transport units following chopper 7. Short chopping required to prevent knitting of feed and consequent unloading difficulties

TABLE J1. (continued)

Form of Forage	Advantages	Considerations
Chopped hay[ab]	1. Adaptability to self-feeding 2. Bulk handling and reduced field labour	1. High field losses 2. Dusty due to pulverized leaves 3. Lower palatability due to leaf-stem separation
Long loose hay[c]	1. High overall capacity 2. Stack storage and reduced labour 3. Safe storage at relatively high moistures 4. Adaptability to self-feeding	1. Heavy leaf losses 2. Increased requirement for storage space 3. Not commercially adapted 4. Resists mechanized feeding
Heat cured bales, wagon batch[a]	1. Greater nutrient retention 2. Reduced weather risk 3. Baled the day it is cut	1. Capacity limited by the number of wagons 2. Drier costs and supervision
Heat-cured bales, shed batch[a]	1. Greater nutrient retention 2. Reduced weather risk 3. Baled the day it is cut	1. Requires shed adaptation 2. High labour requirement 3. Drier costs and supervision
Random-handled, mow-finished bales[a]	1. Low labour requirements 2. Reduced weather risk	1. Higher storage space requirement 2. Ducting and blower or drier required
Random-handled, field-cured bales[a]	1. High risk of weather damage 2. Low labour requirements relative to other bale systems	1. Higher storage space requirement

TABLE J1. (continued)

Form of Forage	Advantages	Considerations
Wafers[a]	1. Mechanized feeding 2. Lower storage space requirements 3. Permits bulk handling	1. High initial cost 2. Higher power requirements and lower operating capacity 3. Requires a high legume content in forage 4. Package failure

[a]Some suggestions taken from Hundtoft and Guest (62).

[b]See Zimmerman (131) for further discussion.

[c]See Zimmerman (132) for further discussion.

TABLE J2. EVALUATION OF FORAGE-HANDLING EQUIPMENT ALTERNATIVES

Item of Machinery	Advantages	Considerations
Forage harvester, flywheel-type cutterhead[a]	1. Attachment versatility 2. Uniform length of cut 3. Less critical adjustment 4. Inexpensive knife replacement	1. High power requirement 2. Somewhat lower capacity 3. High initial cost
Forage harvester, cylinder-type cutterhead[a]	1. Greater capacity 2. Higher speed of operation 3. Uniform length of cut 4. Attachment versatility	1. Greater power requirement 2. Costly knife replacement 3. High initial cost
Forage harvester, flail-type[a]	1. Low initial cost 2. Built-in versatility 3. Simple design and operation 4. Low relative power requirement	1. Higher field losses, higher stubble height 2. Limited row crop use 3. Non-uniform length of cut 4. Prone to foreign matter damage
Crushers and crimpers[bc]	1. Increased drying rate (more pronounced in legumes than in grasses) 2. Field losses reduced (if practice has been to rake when too dry)	1. Greater moisture pick-up at night 2. Matting if rained on 3. Cannot handle wads effectively 4. Some leaf stripping
Fluffers and tedders[b]	1. Simple low-cost machines 2. High travel speeds 3. Increased swath aeration	1. Optimal tedding moisture content is also optimal raking content (i.e., about 50%) 2. Only influences drying rate when hay has been rained on 3. Crushers and crimpers with roll tension relieved can be used for the same purpose
Side-delivery rake[b]		1. High leaf loss 2. Trash can be largely excluded

TABLE J2. (continued)

Item of Machinery	Advantages	Considerations
Parallel-bar rake[b]	1. Speed of impact between teeth and hay is about 25% of the above 2. Hay moves shorter distance, therefore leaf loss reduced	1. Trash can be largely excluded
Wheel rake[b]	1. Low cost, simple design 2. Rakes clean even on rough terrain 3. High speeds possible with contact speed about half of the above	1. Wind deflectors required on windy days 2. Trash cannot be excluded
Drag conveyor rake[b]	1. Hay movement minimized 2. Lighter windrow 3. Can be used to scatter a wet windrow into a swath	1. Higher contact speeds
Multi-treatment machines[b]	1. 'Once-over' reduces handling, therefore losses	1. Deflectors used to form windrow 2. Extended drying time in some cases
Flail choppers[b]	1. Versatility 2. Faster drying than mowed-crushed hay 3. Effective in heavy, lodged or tangled crops	1. Increased stubble height 2. Matting after rain 3. Losses increased since leaves and chopped material not picked up by the rake
Flail mowers[b]	1. Losses likely low if no movement of windrow required 2. Versatility	1. Higher stubble 2. Increased leaf and clipping losses 3. Higher power requirement
Rotary mowers[b]	1. Compact uniform windrow 2. Losses likely low if no movement of windrow required 3. Versatility	1. Better performance as dryness of standing crop and field increases 2. Tractor wheels depress standing crop

TABLE J2. (continued)

Item of Machinery	Advantages	Considerations
Self-propelled windrower plus conditioner[bc]	1. High field capacity 2. Uniform windrow 3. Reduced leaf loss even if turned 4. Lodged hay is more easily cut 5. Trash in the hay is eliminated 6. Hay is air-cured, therefore bleaching is reduced	1. Higher stubble 2. High initial cost 3. Longer curing time
Bale loader[c]	1. Postpones handling	1. Added expense 2. Field travel increased
Self-propelled bale wagon[c]	1. Multi-functional 2. Postpones bale handling	1. High initial cost 2. Ground-level storage only
Bale accumulator[c]	1. Bulk handling 2. Reduced field travel	1. Extra power required
Bale thrower[c]	1. Part of a system 2. Reduced handling costs	1. Increased twine requirement 2. Wagon and storage space lost

[a]See Zimmerman (131) for further discussion.

[b]See Hundtoft (61) for further discussion.

[c]See Zimmerman (128) for further discussion.

APPENDIX K

RANKED OUTPUT OF SIMULATED SYSTEMS

The results of the simulation programs were first grouped according to the type of field machinery used during harvesting and then, within each group, the individual machinery systems were ranked in ascending order of cost per ton of digestible protein fed. Subsequently, these systems were ranked, by group, in ascending order of lowest cost per ton of digestible protein fed.

Note that the total cost was charged proportionately to protein and energy. Therefore, although the forage was considered as a source of both protein and energy, systems were ranked on the basis of protein cost.

The ranked results of the simulation are given in tables K1 and K3 for 200 acres and in tables K2 and K4 for 300 acres of forage. The list of nodes given for any one simulated system includes only those nodes met enroute that uniquely define the system. These node numbers relate to figures 5, 6 and 21. For purposes of comparison, the total cost figure is given as cost per ton of dry matter fed. Note that a slightly higher cost per ton of dry matter does not always mean increased cost per ton of digestible protein fed.

TABLE K1. FORAGE HANDLING SYSTEMS SIMULATED FOR 200 ACRES - DIRECT-CUT HARVESTING.

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
1	22,52,73,42,82,89	100.	24.
2	22,52,73,42,82,105	117.	28.
3	22,52,73,42,82,105	118.	28.
4	22,52,73,42,82,105	123.	29.
5	22,52,73,42,82,89	125.	31.
6	22,52,73,42,82,105	131.	30.
7	22,52,73,42,82,105	133.	31.
8	22,52,73,42,82,89	140.	33.
9	22,52,73,42,82,89	143.	33.
10	22,52,73,42,82,89	146.	34.
11	22,52,73,42,82,111	197.	47.
12	22,52,73,42,82,111	213.	51.
13	22,52,73,42,82,111	214.	52.
14	22,52,73,42,82,111	221.	52.
15	22,52,74,42,82,105	101.	25.
16	22,52,74,42,82,105	126.	30.
17	22,52,74,42,82,105	136.	32.
18	22,52,74,42,82,89	139.	32.
19	22,52,74,42,82,105	140.	34.
20	22,52,74,42,82,111	212.	51.
21	22,52,74,42,82,111	223.	52.
22	22,52,74,42,82,111	240.	58.
23	22,52,74,42,82,111	299.	71.
24	23,52,73,42,82,105	101.	24.
25	23,52,73,42,82,105	106.	26.
26	23,52,73,42,82,105	119.	29.
27	23,52,73,42,82,89	127.	30.
28	23,52,73,42,82,105	132.	32.
29	23,52,71,42,83,105	104.	25.
30	23,52,71,42,83,105	125.	30.
31	23,52,71,42,83,105	137.	30.
32	23,52,71,42,83,89	227.	53.
33	23,52,71,42,83,111	245.	56.
34	23,52,71,42,83,111	252.	60.
35	23,52,71,42,83,111	269.	63.
36	21,52,72,42,82,105	105.	25.
37	21,52,72,42,82,105	128.	30.
38	21,52,72,42,82,89	171.	40.
39	21,52,72,42,82,111	233.	54.
40	21,52,72,42,82,89	236.	55.
41	21,52,72,42,82,89	254.	58.

TABLE K1. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
42	21,52,72,42,82,111	276.	65.
43	21,52,72,42,82,111	325.	75.
44	21,52,72,42,83,105	107.	25.
45	21,52,72,42,83,105	107.	25.
46	21,52,72,42,83,105	118.	27.
47	21,52,72,42,83,105	126.	29.
48	21,52,72,42,83,89	210.	48.
49	21,52,72,42,83,111	262.	61.
50	21,52,72,42,83,111	302.	70.
51	21,52,72,42,83,111	311.	73.
52	21,52,72,42,83,89	346.	81.
53	22,52,74,42,83,89	109.	26.
54	22,52,74,42,83,89	124.	28.
55	22,52,74,42,83,89	126.	30.
56	22,52,74,42,83,89	144.	35.
57	22,52,74,42,83,89	156.	36.
58	22,52,74,42,83,111	226.	53.
59	22,52,74,42,83,111	288.	69.
60	22,52,74,42,83,111	300.	71.
61	22,52,74,42,83,111	359.	84.
62	23,52,73,42,83,89	109.	26.
63	23,52,73,42,83,105	115.	28.
64	23,52,73,42,83,89	121.	29.
65	23,52,73,42,83,89	122.	30.
66	23,52,73,42,83,105	124.	29.
67	23,52,73,42,83,105	127.	31.
68	23,52,73,42,83,111	227.	54.
69	23,52,73,42,83,111	228.	54.
70	23,52,73,42,83,111	383.	80.
71	23,52,72,42,82,105	109.	26.
72	23,52,72,42,82,105	129.	30.
73	23,52,72,42,82,89	187.	44.
74	23,52,72,42,82,111	250.	56.
75	22,52,73,42,83,89	111.	27.
76	22,52,73,42,83,89	131.	31.
77	22,52,73,42,83,105	137.	33.
78	22,52,73,42,83,111	205.	50.
79	22,52,73,42,83,111	222.	52.
80	22,52,73,42,83,111	254.	60.
81	22,52,73,42,83,111	261.	63.
82	23,52,74,42,82,105	113.	27.
83	23,52,74,42,82,89	113.	27.
84	23,52,74,42,82,105	113.	27.

TABLE K1. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
85	23,52,74,42,82,89	127.	30.
86	23,52,74,42,82,89	129.	31.
87	23,52,74,42,82,105	130.	31.
88	23,52,74,42,82,105	132.	31.
89	23,52,74,42,82,105	133.	32.
90	23,52,74,42,82,89	151.	35.
91	21,52,74,42,83,105	114.	27.
92	21,52,74,42,83,89	122.	29.
93	21,52,74,42,83,89	130.	31.
94	21,52,74,42,83,89	150.	35.
95	21,52,74,42,83,89	167.	36.
96	21,52,74,42,83,111	225.	54.
97	21,52,74,42,83,111	302.	70.
98	23,52,71,42,82,105	117.	28.
99	23,52,71,42,82,105	127.	30.
100	23,52,71,42,82,89	185.	45.
101	23,52,71,42,82,111	233.	53.
102	23,52,71,42,82,111	260.	62.
103	23,52,71,42,82,89	275.	65.
104	23,52,71,42,82,89	280.	66.
105	23,52,71,42,82,89	287.	69.
106	23,52,71,42,82,111	315.	75.
107	23,52,72,42,83,105	118.	28.
108	23,52,72,42,83,105	126.	30.
109	23,52,72,42,83,89	207.	49.
110	23,52,72,42,83,89	242.	57.
111	23,52,72,42,83,111	285.	67.
112	23,52,72,42,83,89	346.	79.
113	21,52,73,42,83,105	118.	28.
114	21,52,73,42,83,105	125.	30.
115	21,52,73,42,83,89	130.	31.
116	21,52,73,42,83,89	131.	30.
117	21,52,73,42,83,105	141.	34.
118	21,52,73,42,83,111	205.	47.
119	21,52,73,42,83,111	233.	56.
120	23,52,74,42,83,105	119.	29.
121	23,52,74,42,83,105	122.	29.
122	23,52,74,42,83,89	126.	30.
123	23,52,74,42,83,89	127.	31.
124	23,52,74,42,83,89	134.	32.
125	23,52,74,42,83,105	135.	32.
126	23,52,74,42,83,89	137.	30.

TABLE K1. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
127	23,52,74,42,83,105	142.	33.
128	23,52,74,42,83,89	148.	35.
129	23,52,74,42,83,111	255.	61.
130	21,52,73,42,82,89	120.	29.
131	21,52,73,42,82,105	124.	28.
132	21,52,73,42,82,105	129.	29.
133	21,52,73,42,82,105	141.	31.
134	21,52,73,42,82,89	146.	34.
135	21,52,73,42,82,111	339.	80.
136	22,52,71,42,83,105	123.	29.
137	22,52,71,42,83,105	136.	32.
138	22,52,71,42,83,105	139.	32.
139	22,52,71,42,83,111	163.	39.
140	22,52,71,42,83,111	175.	42.
141	22,52,71,42,83,111	229.	53.
142	22,52,71,42,83,89	280.	64.
143	21,52,74,42,82,105	124.	30.
144	21,52,74,42,82,89	134.	30.
145	21,52,74,42,82,89	144.	33.
146	21,52,74,42,82,111	249.	59.
147	21,52,74,42,82,111	267.	62.
148	22,52,72,42,83,105	125.	30.
149	22,52,72,42,83,89	208.	50.
150	22,52,72,42,83,111	393.	88.
151	22,52,72,42,82,105	125.	29.
152	22,52,72,42,82,89	198.	47.
153	22,52,72,42,82,111	203.	48.
154	22,52,72,42,82,111	233.	53.
155	22,52,72,42,82,89	262.	62.
156	24,52,71,42,82,105	128.	31.
157	24,52,71,42,82,105	135.	32.
158	24,52,71,42,82,111	252.	59.
159	24,52,71,42,82,111	262.	63.
160	24,52,71,42,82,89	267.	64.
161	21,52,71,42,82,105	129.	30.
162	21,52,71,42,82,105	129.	30.
163	21,52,71,42,82,89	249.	58.
164	21,52,71,42,82,89	279.	61.
165	21,52,71,42,82,89	304.	68.

TABLE K1. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
166	21,51,72,42,82,105	129.	30.
167	21,51,72,42,82,89	219.	52.
168	21,51,72,42,82,89	224.	52.
169	21,51,72,42,82,89	248.	56.
170	21,51,72,42,82,111	259.	60.
171	21,51,72,42,82,89	291.	68.
172	21,51,72,42,82,111	293.	69.
173	21,51,72,42,82,89	350.	82.
174	21,51,72,42,82,111	372.	86.
175	21,51,72,42,82,89	399.	92.
176	21,51,71,42,83,105	130.	30.
177	21,51,71,42,83,105	176.	41.
178	21,51,71,42,83,89	248.	56.
179	21,51,71,42,83,111	297.	68.
180	21,51,71,42,83,89	330.	77.
181	24,52,71,42,83,105	136.	33.
182	24,52,71,42,83,105	159.	37.
183	24,52,71,42,83,105	166.	37.
184	24,52,71,42,83,105	172.	39.
185	24,52,71,42,83,89	329.	77.
186	24,52,71,42,83,89	338.	78.
187	24,52,71,42,83,89	347.	84.
188	24,52,74,42,83,89	317.	34.
189	24,52,74,42,83,89	148.	36.
190	24,52,74,42,83,105	152.	36.
191	24,52,74,42,83,105	159.	37.
192	24,52,74,42,83,105	171.	40.
193	24,52,74,42,83,89	176.	43.
194	24,52,74,42,83,111	341.	83.
195	24,52,72,42,82,105	139.	33.
196	24,52,72,42,82,111	263.	63.
197	24,52,72,42,82,111	287.	68.
198	24,52,72,42,82,89	305.	72.
199	24,52,72,42,82,111	403.	91.
200	22,51,72,42,83,105	140.	33.
201	22,51,72,42,83,105	170.	41.
202	22,51,72,42,83,111	279.	66.
203	22,51,72,42,83,111	293.	68.
204	22,51,72,42,83,111	297.	72.
205	22,51,72,42,83,89	350.	82.
206	22,51,72,42,83,111	365.	84.
207	22,51,72,42,83,89	400.	93.

TABLE K1. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
208	22,51,71,42,83,105	142.	33.
209	22,51,71,42,83,105	192.	45.
210	22,51,71,42,83,111	295.	71.
211	22,51,71,42,83,89	313.	75.
212	22,51,71,42,83,89	326.	76.
213	22,51,73,42,83,105	142.	35.
214	22,51,73,42,83,89	151.	37.
215	22,51,73,42,83,89	190.	45.
216	22,51,71,42,82,105	142.	34.
217	22,51,71,42,82,105	151.	35.
218	22,51,71,42,82,105	199.	47.
219	22,51,71,42,82,111	280.	65.
220	22,51,71,42,82,89	328.	79.
221	22,51,71,42,82,89	424.	102.
222	23,51,72,42,83,105	143.	34.
223	23,51,72,42,83,105	152.	36.
224	23,51,72,42,83,105	177.	42.
225	23,51,72,42,83,111	250.	60.
226	23,51,72,42,83,111	262.	63.
227	23,51,72,42,83,111	263.	61.
228	23,51,72,42,83,111	272.	64.
229	23,51,72,42,83,89	288.	67.
230	23,51,72,42,83,111	289.	70.
231	23,51,72,42,83,111	366.	87.
232	23,51,72,42,83,111	385.	91.
233	23,51,72,42,83,111	447.	107.
234	22,51,72,42,82,105	143.	34.
235	22,51,72,42,82,105	168.	40.
236	22,51,72,42,82,89	273.	65.
237	22,51,72,42,82,89	343.	82.
238	22,51,72,42,82,89	353.	84.
239	23,51,74,42,83,89	144.	35.
240	23,51,74,42,83,89	157.	37.
241	23,51,74,42,83,111	396.	93.
242	24,52,74,42,82,105	148.	36.
243	24,52,74,42,82,105	152.	37.
244	24,52,74,42,82,89	154.	38.
245	24,52,74,42,82,105	174.	41.
246	24,52,74,42,82,89	176.	41.
247	24,52,74,42,82,111	410.	99.

TABLE K1. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
248	24,52,72,42,83,105	151.	36.
249	24,52,72,42,83,89	213.	51.
250	24,52,72,42,83,111	280.	66.
251	24,52,72,42,83,111	340.	79.
252	24,52,72,42,83,111	363.	86.
253	23,51,72,42,82,105	151.	36.
254	23,51,72,42,82,105	159.	38.
255	23,51,72,42,82,89	208.	50.
256	23,51,72,42,82,111	224.	53.
257	23,51,72,42,82,111	243.	58.
258	23,51,72,42,82,111	329.	78.
259	23,51,72,42,82,111	360.	86.
260	22,51,73,42,82,105	152.	37.
261	22,51,73,42,82,89	178.	43.
262	22,51,73,42,82,89	194.	46.
263	22,51,73,42,82,105	196.	48.
264	22,51,73,42,82,89	202.	49.
265	22,51,73,42,82,89	222.	52.
266	22,51,73,42,82,111	336.	75.
267	21,51,73,42,82,89	154.	36.
268	21,51,73,42,82,89	171.	39.
269	21,51,73,42,82,105	180.	42.
270	21,51,73,42,82,111	314.	74.
271	21,51,73,42,82,111	331.	79.
272	21,51,73,42,82,111	429.	102.
273	21,51,73,42,82,111	435.	101.
274	21,51,74,42,82,105	155.	37.
275	21,51,74,42,82,105	169.	40.
276	21,51,74,42,82,89	174.	41.
277	21,51,74,42,82,105	184.	42.
278	21,51,74,42,82,105	187.	44.
279	21,51,74,42,82,89	189.	44.
280	21,51,74,42,82,111	250.	58.
281	21,51,74,42,82,111	253.	59.
282	21,51,74,42,82,111	273.	65.
283	23,51,71,42,82,105	157.	38.
284	23,51,71,42,82,105	177.	43.
285	23,51,71,42,82,105	181.	41.
286	23,51,71,42,82,89	277.	63.
287	23,51,71,42,82,89	281.	67.
288	23,51,71,42,82,111	289.	69.

TABLE K1. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
289	23,51,71,42,82,89	364.	82.
290	23,51,71,42,82,111	400.	91.
291	24,52,73,42,82,89	157.	37.
292	24,52,73,42,82,89	173.	41.
293	24,52,73,42,82,111	250.	61.
294	22,51,74,42,82,89	157.	37.
295	22,51,74,42,82,89	178.	41.
296	22,51,74,42,82,89	190.	45.
297	22,51,74,42,82,105	199.	47.
298	22,51,74,42,82,89	204.	49.
299	22,51,74,42,82,111	260.	63.
300	22,51,74,42,82,111	322.	71.
301	22,51,74,42,82,111	485.	111.
302	23,51,74,42,82,105	158.	38.
303	23,51,74,42,82,89	165.	39.
304	23,51,74,42,82,105	173.	41.
305	23,51,74,42,82,105	189.	44.
306	23,51,74,42,82,111	395.	95.
307	24,52,73,42,83,89	159.	38.
308	24,52,73,42,83,105	167.	39.
309	24,52,73,42,83,105	168.	39.
310	24,52,73,42,83,105	174.	41.
311	24,52,73,42,83,111	260.	62.
312	24,52,73,42,83,111	290.	70.
313	24,52,73,42,83,111	334.	81.
314	21,51,72,42,83,105	161.	38.
315	21,51,72,42,83,105	165.	39.
316	21,51,72,42,83,105	189.	44.
317	21,51,72,42,83,105	205.	47.
318	21,51,72,42,83,111	232.	54.
319	21,51,72,42,83,111	244.	56.
320	23,51,73,42,82,105	164.	39.
321	23,51,73,42,82,105	184.	44.
322	23,51,73,42,82,89	232.	55.
323	23,51,73,42,82,111	243.	59.
324	23,51,73,42,82,111	349.	84.
325	23,51,73,42,82,111	373.	90.
326	23,51,73,42,82,111	410.	98.
327	24,51,72,42,82,105	164.	40.
328	24,51,72,42,82,89	339.	80.
329	24,51,72,42,82,89	396.	90.

TABLE K1. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
330	22,51,74,42,83,105	164.	39.
331	22,51,74,42,83,89	198.	46.
332	22,51,74,42,83,89	210.	47.
333	22,51,74,42,83,111	256.	60.
334	22,51,74,42,83,111	333.	79.
335	21,51,74,42,83,89	165.	39.
336	21,51,74,42,83,89	168.	39.
337	21,51,74,42,83,105	179.	41.
338	21,51,74,42,83,89	191.	45.
339	21,51,74,42,83,111	301.	71.
340	21,51,74,42,83,111	307.	71.
341	21,51,74,42,83,111	363.	87.
342	21,51,74,42,83,111	288.	93.
343	23,51,71,42,83,105	167.	38.
344	23,51,71,42,83,111	244.	56.
345	23,51,71,42,83,89	282.	68.
346	23,51,71,42,83,111	367.	88.
347	23,51,73,42,83,105	168.	40.
348	23,51,73,42,83,89	172.	41.
349	23,51,73,42,83,89	174.	42.
350	23,51,73,42,83,89	184.	44.
351	23,51,73,42,83,105	191.	46.
352	21,51,73,42,83,105	181.	42.
353	21,51,73,42,83,111	346.	82.
354	21,51,73,42,83,111	361.	86.
355	21,51,73,42,83,111	422.	101.
356	24,51,71,42,82,105	184.	44.
357	24,51,71,42,82,111	254.	61.
358	24,51,71,42,82,111	296.	70.
359	24,51,71,42,82,111	336.	81.
360	24,51,71,42,82,111	393.	95.
361	24,51,73,42,82,105	186.	45.
362	24,51,73,42,82,89	202.	48.
363	24,51,73,42,82,89	212.	51.
364	24,51,73,42,82,89	252.	59.
365	24,51,73,42,82,111	304.	74.
366	24,51,73,42,82,89	312.	73.
367	24,51,73,42,82,111	360.	86.
368	24,51,73,42,82,111	378.	90.

TABLE K1. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
369	24,51,74,42,82,89	195.	46.
370	24,51,74,42,82,105	206.	48.
371	24,51,74,42,82,105	221.	54.
372	24,51,74,42,82,105	244.	55.
373	24,51,74,42,82,111	339.	80.
374	24,51,74,42,82,111	354.	83.
375	24,51,74,42,82,111	373.	88.
376	24,51,74,42,82,111	405.	98.
377	24,51,72,42,83,105	197.	45.
378	24,51,72,42,83,89	244.	59.
379	24,51,72,42,83,89	267.	64.
380	24,51,72,42,83,89	294.	70.
381	24,51,72,42,83,89	299.	71.
382	24,51,72,42,83,89	319.	77.
383	24,51,72,42,83,111	387.	94.
384	24,51,73,42,83,105	202.	46.
385	24,51,73,42,83,89	205.	48.
386	24,51,73,42,83,105	209.	50.
387	24,51,73,42,83,89	252.	56.
388	24,51,73,42,83,111	337.	81.
389	24,51,73,42,83,111	406.	95.
390	24,51,74,42,83,89	203.	47.
391	24,51,74,42,83,105	204.	50.
392	24,51,74,42,83,89	242.	58.
393	24,51,74,42,83,111	294.	69.
394	24,51,74,42,83,111	362.	88.
395	24,51,74,42,83,111	366.	86.
396	24,51,74,42,83,111	451.	106.
397	24,51,74,42,83,111	462.	111.
398	24,51,71,42,83,105	232.	55.
399	24,51,71,42,83,111	292.	69.
400	24,51,71,42,83,111	348.	84.
401	24,51,71,42,83,111	361.	86.
402	24,51,71,42,83,111	369.	88.
403	21,52,71,42,83,111	238.	55.
404	21,52,71,42,83,111	240.	54.
405	21,52,71,42,83,111	305.	69.
406	21,52,71,42,83,89	312.	74.
407	22,52,71,42,82,111	252.	60.
408	22,52,71,42,82,89	262.	61.

TABLE K1. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
409	21,51,71,42,82,89	290.	68.
410	21,51,71,42,82,89	313.	73.
411	21,51,71,42,82,89	410.	95.
412	22,52,72,41	295.	74.
413	22,52,72,41	303.	76.
414	22,52,72,41	303.	76.
415	22,52,72,41	312.	79.
416	22,52,72,41	313.	78.
417	22,52,72,41	314.	78.
418	22,52,72,41	315.	79.
419	22,52,72,41	316.	78.
420	22,52,72,41	332.	84.
421	22,52,72,41	332.	81.
422	22,52,72,41	333.	82.
423	22,52,72,41	340.	82.
424	22,52,72,41	342.	83.
425	22,52,72,41	343.	80.
426	22,52,72,41	346.	85.
427	22,52,72,41	349.	85.
428	22,52,72,41	354.	84.
429	22,52,72,41	362.	86.
430	22,52,72,41	373.	85.
431	22,52,72,41	376.	92.
432	23,52,72,41	299.	74.
433	23,52,72,41	314.	79.
434	23,52,72,41	323.	79.
435	23,52,72,41	326.	81.
436	23,52,72,41	335.	84.
437	23,52,72,41	337.	82.
438	23,52,72,41	350.	85.
439	23,52,72,41	352.	86.
440	23,52,72,41	353.	86.
441	23,52,72,41	353.	88.
442	23,52,72,41	364.	88.
443	22,52,71,41	301.	75.
444	22,52,71,41	311.	77.
445	22,52,71,41	314.	77.
446	22,52,71,41	317.	79.
447	22,52,71,41	318.	79.
448	22,52,71,41	323.	81.
449	22,52,71,41	324.	81.
450	22,52,71,41	330.	83.
451	22,52,71,41	332.	79.
452	22,52,71,41	335.	80.

TABLE K1. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
453	22,52,71,41	340.	85.
454	22,52,71,41	343.	83.
455	22,52,71,41	345.	85.
456	22,52,71,41	347.	85.
457	22,52,71,41	369.	87.
458	22,52,71,41	296.	93.
459	23,52,71,41	305.	76.
460	23,52,71,41	307.	76.
461	23,52,71,41	315.	78.
462	23,52,71,41	318.	78.
463	23,52,71,41	320.	78.
464	23,52,71,41	323.	81.
465	23,52,71,41	323.	80.
466	23,52,71,41	330.	81.
467	23,52,71,41	330.	81.
468	23,52,71,41	336.	81.
469	23,52,71,41	358.	88.
470	23,52,71,41	360.	84.
471	21,52,72,41	312.	77.
472	21,52,72,41	316.	78.
473	21,52,72,41	317.	78.
474	21,52,72,41	320.	77.
475	21,52,72,41	323.	78.
476	21,52,72,41	338.	82.
477	21,52,72,41	338.	82.
478	21,52,72,41	344.	84.
479	21,52,72,41	347.	83.
480	21,52,72,41	354.	85.
481	21,52,72,41	360.	86.
482	21,52,72,41	385.	87.
483	21,52,72,41	389.	94.
484	23,52,73,41	316.	79.
485	23,52,73,41	316.	79.
486	23,52,73,41	324.	81.
487	23,52,73,41	328.	81.
488	23,52,73,41	336.	82.
489	23,52,73,41	341.	82.
490	23,52,73,41	344.	85.
491	23,52,73,41	346.	86.
492	23,52,73,41	349.	87.
493	23,52,74,41	317.	80.
494	23,52,74,41	317.	79.
495	23,52,74,41	322.	81.

TABLE K1. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
496	23,52,74,41	324.	80.
497	23,52,74,41	325.	80.
498	23,52,74,41	326.	81.
499	23,52,74,41	329.	83.
500	23,52,74,41	330.	82.
501	23,52,74,41	341.	84.
502	23,52,74,41	341.	84.
503	23,52,74,41	344.	86.
504	23,52,74,41	345.	84.
505	23,52,74,41	345.	86.
506	23,52,74,41	349.	87.
507	23,52,74,41	351.	87.
508	23,52,74,41	353.	89.
509	22,52,74,41	319.	81.
510	22,52,74,41	323.	81.
511	22,52,74,41	327.	82.
512	22,52,74,41	330.	83.
513	22,52,74,41	334.	82.
514	22,52,74,41	343.	84.
515	22,52,74,41	352.	87.
516	22,52,74,41	355.	88.
517	22,52,74,41	357.	89.
518	22,52,74,41	361.	88.
519	22,52,74,41	369.	89.
520	22,52,74,41	374.	89.
521	21,51,71,41	320.	79.
522	21,51,71,41	336.	81.
523	21,51,71,41	337.	82.
524	21,51,71,41	354.	85.
525	21,51,71,41	363.	88.
526	21,51,71,41	374.	90.
527	21,51,71,41	414.	90.
528	21,52,73,41	320.	79.
529	21,52,73,41	328.	80.
530	21,52,73,41	328.	81.
531	21,52,73,41	333.	79.
532	21,52,73,41	335.	83.
533	21,52,73,41	343.	81.
534	21,52,73,41	346.	86.
535	21,52,73,41	346.	85.
536	21,52,73,41	357.	84.
537	21,52,73,41	357.	86.
538	21,52,73,41	367.	88.

TABLE K1. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
539	22,52,73,41	321.	81.
540	22,52,73,41	322.	80.
541	22,52,73,41	326.	82.
542	22,52,73,41	327.	83.
543	22,52,73,41	333.	83.
544	22,52,73,41	336.	82.
545	22,52,73,41	337.	85.
546	22,52,73,41	340.	84.
547	22,52,73,41	352.	87.
548	22,52,73,41	354.	85.
549	21,51,72,41	322.	79.
550	21,51,72,41	335.	83.
551	21,51,72,41	335.	83.
552	21,51,72,41	342.	83.
553	21,51,72,41	344.	85.
554	21,51,72,41	350.	83.
555	21,51,72,41	357.	83.
556	21,51,72,41	357.	87.
557	21,51,72,41	361.	87.
558	21,51,72,41	366.	88.
559	21,51,72,41	372.	86.
560	21,51,72,41	372.	90.
561	21,51,72,41	378.	92.
562	21,52,74,41	322.	79.
563	21,52,74,41	326.	79.
564	21,52,74,41	329.	80.
565	21,52,74,41	333.	82.
566	21,52,74,41	337.	81.
567	21,52,74,41	340.	82.
568	21,52,74,41	351.	86.
569	21,52,74,41	356.	85.
570	21,52,74,41	368.	85.
571	22,51,72,41	323.	80.
572	22,51,72,41	324.	80.
573	22,51,72,41	326.	80.
574	22,51,72,41	327.	83.
575	22,51,72,41	328.	81.
576	22,51,72,41	328.	81.
577	22,51,72,41	329.	82.
578	22,51,72,41	330.	82.
579	22,51,72,41	331.	82.
580	22,51,72,41	338.	84.
581	22,51,72,41	341.	84.
582	22,51,72,41	344.	83.

TABLE K1. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
583	22,51,72,41	344.	86.
584	22,51,72,41	356.	87.
585	22,51,72,41	360.	87.
586	22,51,72,41	361.	89.
587	22,51,72,41	362.	86.
588	22,51,72,41	364.	89.
589	22,51,72,41	368.	86.
590	22,51,71,41	324.	79.
591	22,51,71,41	341.	84.
592	22,51,71,41	342.	84.
593	22,51,71,41	343.	84.
594	22,51,71,41	347.	85.
595	22,51,71,41	347.	85.
596	22,51,71,41	349.	84.
597	22,51,71,41	351.	84.
598	22,51,71,41	354.	88.
599	22,51,71,41	357.	87.
600	22,51,71,41	362.	88.
601	22,51,71,41	367.	88.
602	22,51,71,41	390.	94.
603	21,52,71,41	325.	79.
604	21,52,71,41	326.	80.
605	21,52,71,41	330.	81.
606	21,52,71,41	331.	81.
607	21,52,71,41	331.	79.
608	21,52,71,41	343.	78.
609	21,52,71,41	348.	84.
610	21,52,71,41	348.	84.
611	21,52,71,41	361.	85.
612	23,51,71,41	326.	80.
613	23,51,71,41	343.	86.
614	23,51,71,41	345.	84.
615	23,51,71,41	347.	85.
616	23,51,71,41	349.	87.
617	23,51,71,41	355.	86.
618	23,51,71,41	358.	89.
619	23,51,71,41	359.	87.
620	23,51,71,41	362.	88.
621	23,51,71,41	365.	87.
622	23,51,71,41	376.	91.

TABLE K1. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
623	24,51,72,41	328.	82.
624	24,51,72,41	337.	84.
625	24,51,72,41	343.	86.
626	24,51,72,41	344.	85.
627	24,51,72,41	358.	90.
628	24,51,72,41	360.	90.
629	24,51,72,41	363.	89.
630	24,51,72,41	367.	90.
631	24,51,72,41	373.	89.
632	24,51,72,41	375.	92.
633	24,51,72,41	382.	94.
634	24,51,72,41	391.	97.
635	24,51,72,41	397.	96.
636	24,52,72,41	330.	83.
637	24,52,72,41	334.	83.
638	24,52,72,41	341.	85.
639	24,52,72,41	344.	85.
640	24,52,72,41	352.	87.
641	24,52,72,41	356.	88.
642	24,52,72,41	363.	89.
643	24,52,72,41	369.	91.
644	24,52,72,41	371.	91.
645	24,52,72,41	371.	89.
646	24,52,72,41	401.	95.
647	23,51,72,41	331.	82.
648	23,51,72,41	331.	82.
649	23,51,72,41	334.	83.
650	23,51,72,41	334.	81.
652	23,51,72,41	339.	85.
653	23,51,72,41	340.	85.
654	23,51,72,41	342.	85.
655	23,51,72,41	343.	85.
656	23,51,72,41	349.	85.
657	23,51,72,41	350.	87.
658	23,51,72,41	383.	91.
659	23,51,72,41	386.	91.
660	23,51,74,41	331.	84.
661	23,51,74,41	344.	87.
662	23,51,74,41	344.	85.
663	23,51,74,41	349.	88.
664	23,51,74,41	364.	91.
665	23,51,74,41	365.	92.
666	23,51,74,41	401.	98.
667	23,51,74,41	409.	99.

TABLE K1. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
668	24,52,71,41	332.	84.
669	24,52,71,41	332.	82.
670	24,52,71,41	345.	85.
671	24,52,71,41	346.	87.
672	24,52,71,41	347.	86.
673	24,52,71,41	347.	85.
674	24,52,71,41	349.	86.
675	24,52,71,41	352.	87.
676	24,52,71,41	354.	89.
677	24,52,71,41	357.	88.
678	24,52,71,41	359.	89.
679	24,52,71,41	361.	89.
680	24,52,71,41	361.	88.
681	24,52,71,41	363.	90.
682	24,52,71,41	369.	93.
683	24,52,71,41	369.	91.
684	24,52,71,41	372.	90.
685	24,52,71,41	372.	92.
686	24,52,71,41	392.	91.
687	21,51,74,41	333.	83.
688	21,51,74,41	346.	84.
689	21,51,74,41	351.	85.
690	21,51,74,41	354.	87.
691	21,51,74,41	355.	88.
692	21,51,74,41	362.	89.
693	21,51,74,41	366.	91.
694	21,51,74,41	366.	90.
695	21,51,74,41	368.	88.
696	21,51,74,41	377.	91.
697	21,51,74,41	378.	92.
698	21,51,74,41	379.	94.
699	21,51,74,41	382.	89.
700	21,51,74,41	403.	90.
701	21,51,74,41	412.	95.
702	22,51,74,41	341.	86.
703	22,51,74,41	342.	84.
704	22,51,74,41	346.	86.
705	22,51,74,41	351.	88.
706	22,51,74,41	359.	91.
707	22,51,74,41	362.	92.
708	22,51,74,41	366.	91.
709	22,51,74,41	378.	90.
710	22,51,74,41	394.	96.
711	22,51,74,41	410.	100.
712	22,51,74,41	422.	95.

TABLE K1. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
713	24,52,74,41	341.	86.
714	24,52,74,41	342.	87.
715	24,52,74,41	346.	87.
716	24,52,74,41	348.	87.
717	24,52,74,41	352.	87.
718	24,52,74,41	354.	89.
719	24,52,74,41	354.	88.
720	24,52,74,41	355.	89.
721	24,52,74,41	359.	91.
722	24,52,74,41	359.	89.
723	24,52,74,41	359.	86.
724	24,52,74,41	361.	87.
725	24,52,74,41	362.	90.
726	24,52,74,41	366.	91.
727	24,52,74,41	366.	92.
728	24,52,74,41	370.	93.
729	24,52,74,41	375.	95.
730	24,52,74,41	379.	88.
731	24,51,71,41	347.	87.
732	24,51,71,41	348.	87.
733	24,51,71,41	354.	88.
734	24,51,71,41	356.	87.
735	24,51,71,41	360.	88.
736	24,51,71,41	362.	86.
737	24,51,71,41	366.	90.
738	24,51,71,41	368.	89.
739	24,51,71,41	373.	94.
740	24,51,71,41	381.	94.
741	24,51,71,41	382.	93.
742	24,51,71,41	388.	94.
743	24,51,71,41	397.	98.
744	24,52,73,41	350.	87.
745	24,52,73,41	351.	88.
746	24,52,73,41	351.	88.
747	24,52,73,41	352.	89.
748	24,52,73,41	360.	91.
749	24,52,73,41	360.	89.
750	24,52,73,41	365.	91.
751	22,51,73,41	356.	88.
752	22,51,73,41	367.	93.
753	22,51,73,41	370.	92.
754	22,51,73,41	372.	93.
755	22,51,73,41	387.	97.
756	22,51,73,41	389.	96.
757	22,51,73,41	390.	97.

TABLE K1. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
758	22,51,73,41	394.	100.
759	22,51,73,41	400.	98.
760	22,51,73,41	404.	100.
761	22,51,73,41	412.	101.
762	22,51,73,41	447.	106.
763	24,51,74,41	362.	91.
764	24,51,74,41	362.	89.
765	24,51,74,41	373.	93.
766	24,51,74,41	379.	93.
767	24,51,74,41	379.	95.
768	24,51,74,41	387.	96.
769	24,51,74,41	393.	100.
770	24,51,74,41	394.	91.
771	24,51,74,41	400.	99.
772	24,51,74,41	416.	105.
773	24,51,74,41	421.	102.
774	23,51,73,41	371.	93.
775	23,51,73,41	371.	93.
776	23,51,73,41	377.	93.
777	23,51,73,41	388.	96.
778	23,51,73,41	392.	98.
779	23,51,73,41	395.	96.
780	23,51,73,41	401.	101.
781	23,51,73,41	434.	100.
782	21,51,73,41	372.	90.
783	21,51,73,41	376.	92.
784	21,51,73,41	389.	96.
785	21,51,73,41	391.	96.
786	21,51,73,41	401.	99.
787	21,51,73,41	402.	100.
788	21,51,73,41	413.	100.
789	21,51,73,41	440.	108.
790	24,51,73,41	393.	98.
791	24,51,73,41	400.	100.
792	24,51,73,41	407.	102.
793	24,51,73,41	411.	102.
794	24,51,73,41	412.	102.
795	24,51,73,41	423.	105.
796	24,51,73,41	427.	102.
797	24,51,73,41	428.	108.
798	24,51,73,41	448.	111.
799	24,51,73,41	468.	116.
800	24,51,73,41	470.	109.

TABLE K2. FORAGE HANDLING SYSTEMS SIMULATED FOR 300 ACRES - DIRECT-CUT HARVESTING.

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	$/T DM Fed
1	22,52,73,42,82,89	96.	23.
2	22,52,73,42,82,105	109.	26.
3	22,52,73,42,82,105	111.	27.
4	22,52,73,42,82,105	113.	27.
5	22,52,73,42,82,105	122.	28.
6	22,52,73,42,82,89	126.	29.
7	22,52,73,42,82,105	130.	30.
8	22,52,73,42,82,89	135.	31.
9	22,52,73.42,82.89	140.	32.
10	22,52,73,42,82,89	142.	32.
11	22,52,73,42,82,111	186.	45.
12	22,52,73,42,82,111	202.	48.
13	22,52,73,42,82,111	212.	50.
14	22,52,73,42,82,111	226.	51.
15	23,52,73,42,82,105	101.	24.
16	23,52,73,42,82,105	108.	24.
17	23,52,73,42,82,105	116.	27.
18	23,52,73,42,82,89	118.	28.
19	23,52,73,42,82,105	134.	31.
20	22,52,74,42,83,89	102.	25.
21	22,52,74,42,83,89	107.	25.
22	22,52,74,42,83,89	115.	27.
23	22,52,74,42,83,89	142.	33.
24	22,52,74,42,83,89	147.	34.
25	22,52,74,42,83,111	273.	65.
26	22,52,74,42,83,111	289.	68.
27	22,52,74,42,83,111	387.	85.
28	22,52,74,42,82,105	102.	24.
29	22,52,74,42,82,105	118.	28.
30	22,52,74,42,82,89	129.	30.
31	22,52,74,42,82,105	141.	32.
32	22,52,74,42,82,111	204.	48.
33	22,52,74,42,82,111	206.	49.
34	22,52,74,42,82,111	231.	55.
35	22,52,74,42,82,111	299.	69.
36	23,52,73,42,83,89	103.	24.
37	23,52,73,42,83,105	116.	27.
38	23,52,73,42,83,105	117.	27.
39	23,52,73,42,83,105	124.	29.
40	23,52,73,42,83,89	130.	29.

TABLE K2. (continued)

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	$/T DM Fed
41	23,52,73,42,83,89	138.	29.
42	23,52,73,42,83,111	217.	51.
43	23,52,73,42,83,111	228.	52.
44	23,52,73,42,83,111	312.	74.
45	22,52,73,42,83,89	104.	25.
46	22,52,73,42,83,89	125.	29.
47	22,52,73,42,83,105	140.	32.
48	22,52,73,42,83,111	204.	48.
49	22,52,73,42,83,111	211.	50.
50	22,52,73,42,83,111	249.	58.
51	22,52,73,42,83,111	283.	62.
52	23,52,71,42,83,105	105.	25.
53	23,52,71,42,83,105	134.	30.
54	23,52,71 42,83,105	159.	34.
55	23,52,71,42,83,89	223.	51.
56	23,52,71,42,83,111	242.	55.
57	23,52,71,42,83,111	279.	61.
58	23,52,71,42,83,111	279.	63.
59	23,52,74,42,82,105	109.	26.
60	23,52,74,42,82,89	111.	26.
61	23,52,74,42,82,105	118.	27.
62	23,52,74,42,82,89	120.	28.
63	23,52,74,42,82,105	122.	28.
64	23,52,74,42,82,105	125.	30.
65	23,52,74,42,82,89	125.	30.
66	23,52,74,42,82,105	153.	33.
67	23,52,74,42,82,89	157.	35.
68	23,52,72,42,82,105	111.	26.
69	23,52,72,42,82,105	135.	31.
70	23,52,72,42,82,89	193.	44.
71	23,52,72,42,82,111	233.	54.
72	21,52,72,42,83,105	113.	26.
73	21,52,72,42,83,105	116.	26.
74	21,52,72,42,83,105	134.	29.
75	21,52,72,42,83,105	137.	29.
76	21,52,72,42,83,89	238.	50.
77	21,52,72,42,83,111	325.	71.
78	21,52,72,42,83,111	339.	66.
79	21,52,72,42,83,111	348	75.
80	21,52,72,42,83,89	363.	81.

TABLE K2. (continued)

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	$/T DM Fed
81	23,52,74,42,83,105	114.	27.
82	23,52,74,42,83,105	115.	27.
83	23,52,74,42,83,89	115.	27.
84	23,52,74,42,83,89	123.	29.
85	23,52,74,42,83,89	127.	29.
86	23,52,74,42,83,89	129.	30.
87	23,52,74,42,83,105	133.	31.
88	23,52,74,42,83,105	137.	31.
89	23,52,74,42,83,89	148.	33.
90	23,52,74,42,83,111	273.	60.
91	21,52,72,42,82,105	115.	26.
92	21,52,72,42,82,105	137.	30.
93	21,52,72,42,82,89	171.	39.
94	21,52,72,42,82,89	245.	55.
95	21,52,72,42,82,111	252.	55.
96	21,52,72,42,82,89	253.	57.
97	21,52,72,42,82,111	289.	66.
98	21,52,72,42,82,111	337.	75.
99	23,52,71,42,82,105	115.	27.
100	23,52,71,42,82,105	129.	29.
101	23,52,71,42,82,89	193.	44.
102	23,52,71,42,82,111	236.	53.
103	23,52,71,42,82,111	261.	61.
104	23,52,71,42,82,89	283.	64.
105	23,52,71,42,82,89	289.	65.
106	23,52,71,42,82,89	290.	67.
107	23,52,71,42,82,111	322.	75.
108	21,52,73,42,83,105	115.	27.
109	21,52,73,42,83,89	119.	28.
110	21,52,73,42,83,105	129.	30.
111	21,52,73,42,83,105	144.	33.
112	21,52,73,42,83,89	148.	32.
113	21,52,73,42,83,111	192.	44.
114	21,52,73,42,83,111	268.	57.
115	23,52,72,42,83,105	118.	27.
116	23,52,72,42,83,105	140.	31.
117	23,52,72,42,83,89	221.	49.
118	23,52,72,42,83,89	243.	56.
119	23,52,72,42,83,111	288.	66.
120	23,52,72,42,83,89	340.	77.

TABLE K2. (continued)

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	$/T DM Fed
121	21,52,73,42,82,105	119.	26.
122	21,52,73,42,82,105	128.	29.
123	21,52,73,42,82,89	128.	29.
124	21,52,73,42,82,105	138.	30.
125	21,52,73,42,83,89	144.	33.
126	21,52,73,42,82,111	341.	78.
127	21,52,74,42,82,89	119.	27.
128	21,52,74,42,82,105	127.	29.
129	21,52,74,42,82,89	140.	31.
130	21,52,74,42,82,111	261.	60.
131	24,52,71,42,82,105	120.	28.
132	24,52,71,42,82,105	129.	30.
133	24,52,71,42,82,111	237.	54.
134	24,52,71,42,82,111	251.	58.
135	24,52,71,42,82,89	261.	59.
136	21,52,74,42,83,105	126.	28.
137	21,52,74,42,83,89	131.	29.
138	21,52,74,42,83,89	136.	31.
139	21,52,74,42,83,89	151.	34.
140	21,52,74,42,83,89	152.	33.
141	21,52,74,42,83,111	225.	52.
142	21,52,74,42,83,111	312.	69.
143	22,52,72,42,82,105	127.	29.
144	22,52,72,42,82,89	194.	45.
145	22,52,72,42,82,111	209.	48.
146	22,52,72,42,82,111	236.	53.
147	22,52,72,42,82,89	266.	61.
148	24,52,74,42,83,89	127.	30.
149	24,52,74,42,83,89	129.	31.
150	24,52,74,42,83,105	132.	31.
151	24,52,74,42,83,105	132.	31.
152	24,52,74,42,83,105	151.	35.
153	24,52,74,42,83,89	166.	38.
154	24,52,74,42,83,111	323.	75.
155	24,52,71,42,83,105	129.	30.
156	24,52,71,42,83,105	150.	35.
157	24,52,71,42,83,105	155.	34.
158	24,52,71,42,83,105	159.	35.
159	24,52,71,42,83,89	318.	71.
160	24,52,71,42,83,89	336.	77.

TABLE K2. (continued)

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	Total Cost (nearest $) $/T DM Fed
161	24,52,71,42,83,89	366.	78.
162	24,52,72,42,82,105	131.	30.
163	24,52,72,42,82,111	246.	58.
164	24,52,72,42,82,111	266.	62.
165	24,52,72,42,82,89	293.	66.
166	24,52,72,42,82,111	367.	83.
167	24,42,74,42,82,105	133.	32.
168	24,52,74,42,82,89	134.	32.
169	24,52,74,42,82,105	135.	32.
170	24,52,74,42,82,105	157.	36.
171	24,52,74,42,82,89	163.	37.
172	22,51,71,42,83,105	134.	31.
173	22,51,71,42,83,105	194.	44.
174	22,51,71,42,83,111	292.	69.
175	22,51,71,42,83,89	316.	72.
176	22,51,71,42,83,89	318.	73.
177	24,52,73,42,82,89	134.	32.
178	24,52,73,42,83,89	148.	35.
179	24,52,73,42,83,111	225.	54.
180	22,52,71,42,83,105	134.	30.
181	22,52,71,42,83,105	140.	32.
182	22,52,71,42,83,105	142.	32.
183	22,52,71,42,83,111	159.	38.
184	22,52,71,42,83,111	176.	42.
185	22,52,71,42,83,111	240.	53.
186	22,52,71,42,83,89	265.	61.
187	22,52,72,42,83,105	136.	30.
188	22,52,72,42,83,89	209.	49.
189	22,52,72,42,83,111	394.	87.
190	24,52,73,42,83,105	139.	33.
191	24,52,73,42,83,89	145.	33.
192	24,52,73,42,83,105	151.	36.
193	24,52,73,42,83,105	157.	35.
194	24,52,73,42,83,111	241.	56.
195	24,52,73,42,83,111	269.	63.
196	24,52,73,42,83,111	325.	74.

TABLE K2. (continued)

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	$/T DM Fed
197	21,51,72,42,82,105	139.	31.
198	21,51,72,42,82,89	231.	51.
199	21,51,72,42,83,89	250.	55.
200	21,51,72,42,82,89	257.	54.
201	21,51,72,42,82,111	273.	60.
202	21,51,72,42,82,89	300.	67.
203	21,51,72,42,82,111	314.	69.
204	21,51,72,42,82,89	354.	80.
205	21,51,72,42,82,89	394.	90.
206	21,51,72,42,82,111	433.	88.
207	24,52,72,42,83,105	139.	32.
208	24,52,72,42,83,89	192.	45.
209	24,52,72,42,83,111	328.	73.
210	24,52,72,42,83,111	328.	68.
211	24,52,72,42,83,111	375.	82.
212	22,51,72,42,83,105	142.	33.
213	22,51,72,42,83,105	169.	40.
214	22,51,72,42,83,111	288.	65.
215	22,51,72,42,83,111	302.	67.
216	22,51,72,42,83,111	314.	71.
217	22,51,72,42,83,89	340.	78.
218	22,51,72,42,83,111	364.	82.
219	22,51,72,42,83,89	394.	90.
220	21,51,71,42,83,105	143.	31.
221	21,51,71,42,83,105	222.	44.
222	21,51,71,42,83,89	247.	55.
223	21,51,71,42,83,111	314.	68.
224	21,51,71,42,83,89	336.	76.
225	22,51,72,42,82,105	143.	33.
226	22,51,72,42,82,105	170.	40.
227	22,51,72,42,82,89	259.	62.
228	22,51,72,42,82,89	344.	79.
229	22,51,72,42,82,89	373.	83.
230	22,51,71,42,82,105	144.	33.
231	22,51,71,42,82,105	150.	34.
232	22,51,71,42,82,105	199.	46.
233	22,51,71,42,82,111	281.	64.
234	22,51,71,42,82,89	325.	76.
235	22,51,71,42,82,89	423.	99.

TABLE K2. (continued)

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	$/T DM Fed
236	22,51,73,42,83,89	144.	35.
237	22,51,73,42,83,105	145.	34.
238	22,51,73,42,83,89	195.	44.
239	21,52,71,42,82,105	146.	31.
240	21,52,71,42,82,105	155.	32.
241	21,52,71,42,82,89	253.	58.
242	21,52,71,42,82,89	262.	59.
243	21,52,71,42,82,89	306.	68.
244	23,51,74,42,83,89	146.	34.
245	23,51,74,42,83,89	159.	36.
246	23,51,74,42,83,111	389.	91.
247	22,51,73,42,82,105	148.	35.
248	22,51,73,42,82,89	166.	40.
249	22,51,73,42,82,105	192.	46.
250	22,51,73,42,82,89	199.	45.
251	22,51,73,42,82,89	200.	47.
252	22,51,73,42,82,89	218.	50.
253	22,51,73,42,82,111	307.	72.
254	22,51,74,42,82,89	148.	35.
255	22,51,74,42,82,89	155.	37.
256	22,51,74,42,82,89	196.	47.
257	22,51,74,42,82,89	198.	45.
258	22,51,74,42,82,105	199.	45.
259	22,51,74,42,82,111	252.	61.
260	22,51,74,42,82,111	305.	68.
261	22,51,74,42,82,111	473.	108.
262	23,51,71,42,83,105	152.	35.
263	23,51,71,42,83,111	229.	53.
264	23,51,71,42,83,89	302.	67.
265	23,51,71,42,83,111	367.	86.
266	23,51,71,42,82,105	154.	36.
267	23,51,71,42,82,105	174.	40.
268	23,51,71,42,82,105	176.	42.
269	23,51,71,42,82,89	257.	60.
270	23,51,71,42,82,89	287.	65.
271	23,51,71,42,82,111	297.	68.
272	23,51,71,42,82,89	369.	80.
273	23,51,71,42,82,111	384.	88.

TABLE K2. (continued)

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	$/T DM Fed
274	23,51,74,42,82,105	154.	36.
275	23,51,74,42,82,89	157.	37.
276	23,51,74,42,82,105	175.	40.
277	23,51,74,42,82,105	193.	43.
278	23,51,74,42,82,111	412.	93.
279	21,51,73,42,82,89	155.	35.
280	21,51,73,42,82,89	157.	37.
281	21,51,73,42,82,105	186.	42.
282	21,51,73,42,82,111	335.	77.
283	21,51,73,42,82,111	336.	73.
284	21,51,73,42,82,111	439.	101.
285	21,51,73,42,82,111	462.	100.
286	22,51,74,42,83,105	155.	37.
287	22,51,74,42,83,89	191.	44.
288	22,51,74,42,83,89	193.	44.
289	22,51,74,42,83,111	251.	58.
290	22,51,74,42,83,111	338.	77.
291	23,51,72,42,83,105	158.	35.
292	23,51,72,42,83,105	161.	36.
293	23,51,72,42,83,105	185.	41.
294	23,51,72,42,83,111	263.	60.
295	23,51,72,42,83,111	265.	60.
296	23,51,72,42,83,111	272.	62.
297	23,51,72,42,83,111	274.	63.
298	23,51,72,42,83,89	295.	66.
299	23,51,72,42,83,111	304.	69.
300	23,51,72,42,83,111	371.	85.
301	23,51,72,42,83,111	408.	90.
302	23,51,72,42,83,111	445.	105.
303	24,51,72,42,82,105	158.	36.
304	24,51,72,42,82,89	351.	75.
305	24,51,72,42,82,89	367.	83.
306	23,51,72,42,82,105	159.	37.
307	23,51,72,42,82,105	161.	36.
308	23,51,72,42,82,89	215.	49.
309	23,51,72,42,82,111	226.	52.
310	23,51,72,42,82,111	243.	56.
311	23,51,72,42,82,111	355.	78.
312	23,51,72,42,82,111	366.	84.

TABLE K2. (continued)

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	$/T DM Fed
313	21,51,74,42,83,89	160.	37.
314	21,51,74,42,83,89	170.	38.
315	21,51,74,42,83,105	177.	40.
316	21,51,74,42,83,89	192.	44.
317	21,51,74,42,83,111	304.	70.
318	21,51,74,42,83,111	315.	70.
319	21,51,74,42,83,111	393.	86.
320	21,51,74,42,83,111	448.	94.
321	24,51,71,42,82,105	163.	39.
322	24,51,71,42,82,111	250.	57.
323	24,51,71,42,82,111	284.	65.
324	24,51,71,42,82,111	313.	74.
325	24,51,71,42,82,111	392.	88.
326	23,51,73,42,83,105	164.	39.
327	23,51,73,42,83,89	165.	39.
328	23,51,73,42,83,89	169.	40.
329	23,51,73,42,83,89	181.	42.
330	23,51,73,42,83,105	196.	45.
331	23,51,73,42,82,105	169.	39.
332	23,51,73,42,82,105	178.	42.
333	23,51,73,42,82,89	222.	52.
334	23,51,73,42,82,111	251.	58.
335	23,51,73,42,82,111	354.	82.
336	23,51,73,42,82,111	371.	87.
337	23,51,73,42,82,111	401.	94.
338	21,51,74,42,82,105	169.	37.
339	21,51,74,42,82,105	173.	39.
340	21,51,74,42,83,89	184.	40.
341	21,51,74,42,82,105	188.	43.
342	21,51,74,42,82,105	196.	42.
343	21,51,74,42,82,89	200.	44.
344	21,51,74,42,82,111	247.	57.
345	21,51,74,42,82,111	254.	57.
346	21,51,74,42,82,111	280.	64.
347	21,51,72,42,83,105	170.	39.
348	21,51,72,42,83,105	174.	39.
349	21,51,72,42,83,105	200.	44.
350	21,51,72,42,83,105	224.	48.
351	21,51,72,42,83,111	233.	53.
352	21,51,72,42,83,111	252.	56.

TABLE K2. (continued)

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	$/T DM Fed
353	24,51,72,42,83,105	171.	40.
354	24,51,72,42,83,89	230.	54.
355	24,51,72,42,83,89	247.	58.
356	24,51,72,42,83,89	275.	64.
357	24,51,72,42,83,89	305.	70.
358	24,51,72,42,83,89	315.	66.
359	24,51,72,42,83,111	384.	88.
360	24,51,74,42,83,89	174.	41.
361	24,51,74,42,83,105	186.	45.
362	24,51,74,42,83,89	225.	53.
363	24,51,74,42,83,111	321.	77.
364	24,51,74,42,83,111	344.	81.
365	24,51,74,42,83,111	423.	97.
366	24,51,74,42,83,111	448.	103.
367	24,51,73,42,83,105	175.	41.
368	24,51,73,42,83,89	179.	43.
369	24,51,73,42,83,105	188.	45.
370	24,51,73,42,83,89	223.	51.
371	24,51,73,42,83,111	307.	74.
372	24,51,73,42,83,111	372.	87.
373	24,51,74,42,82,89	176.	41.
374	24,51,74,42,82,105	180.	42.
375	24,51,74,42,82,105	204.	49.
376	24,51,74,42,82,105	232.	50.
377	24,51,74,42,82,111	319.	73.
378	24,51,74,42,82,111	333.	77.
379	24,51,74,42,82,111	344.	81.
380	24,51,74,42,82,111	387.	90.
381	21,51,73,42,83,105	177.	41.
382	21,51,73,42,83,111	376.	82.
383	21,51,73,42,83,111	377.	86.
384	21,51,73,42,83,111	442.	100.
385	24,51,73,42,82,105	180	41.
386	24,51,73,42,82,89	186.	44.
387	24,51,73,42,82,89	187.	45.
388	24,51,73,42,82,89	234.	54.
389	24,51,73,42,82,111	282.	67.
390	24,51,73,42,82,89	283.	68.
391	24,51,73,42,82,111	328.	79.
392	24,51,73,42,82,111	396.	85.

TABLE K2. (continued)

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	$/T DM Fed
393	24,51,71,42,83,105	211.	50.
394	24,51,71,42,83,111	273.	63.
395	24,51,71,42,83,111	324.	77.
396	24,51,71,42,83,111	342.	79.
397	24,51,71,42,83,111	372.	82.
398	21,52,71,42,83,111	232.	53.
399	21,52,71,42,83,111	251.	56.
400	21,52,71,42,83,111	327.	70.
401	21,52,71,42,83,89	353.	75.
402	22,52,72,41	237.	58.
403	22,52,72,41	245.	60.
404	22,52,72,41	256.	63.
405	22,52,72,41	256.	62.
406	22,52,72,41	257.	61.
407	22,52,72,41	258.	62.
408	22,52,72,41	260.	64.
409	22,52,72,41	264.	63.
410	22,52,72,41	271.	64.
411	22,52,72,41	276.	66.
412	22,52,72,41	277.	68.
413	22,52,72,41	291.	69.
414	22,52,72,41	291.	69.
415	22,52,72,41	291.	68.
416	22,52,72,41	297.	67.
417	22,52,72,41	298.	68.
418	22,52,72,41	303.	67.
419	22,52,72,41	306.	69.
420	22,52,72,41	321.	71.
421	22,52,72,41	336.	77.
422	22,52,71,41	248.	60.
423	22,52,71,41	253.	61.
424	22,52,71,41	256.	62.
425	22,52,71,41	264.	63.
426	22,52,71,41	267.	63.
427	22,52,71,41	270.	66.
428	22,52,71,41	270.	67.
429	22,52,71,41	274.	65.
430	22,52,71,41	278.	65.
431	22,52,71,41	281.	66.
432	22,52,71,41	289.	70.
433	22,52,71,41	291.	68.
434	22,52,71,41	301.	70.
435	22,52,71,41	301.	70.

TABLE K2. (continued)

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	$/T DM Fed
436	22,52,71,41	305.	70.
437	22,52,71,41	345.	77.
438	22,52,71,42,82,89	252.	58.
439	22,52,71,42,82,111	268.	60.
440	23,52,72,41	252.	59.
441	23,52,72,41	260.	63.
442	23,52,72,41	270.	64.
443	23,52,72,41	271.	66.
444	23,52,72,41	286.	67.
445	23,52,72,41	290.	69.
446	23,52,72,41	294.	72.
447	23,52,72,41	304.	73.
448	23,52,72,41	305.	71.
449	23,52,72,41	306.	71.
450	23,52,72,41	310.	70.
451	22,51,72,41	255.	63.
452	22,51,72,41	263.	64.
453	22,51,72,41	266.	66.
454	22,51,72,41	268.	64.
455	22,51,72,41	269.	66.
456	22,51,72,41	269.	64.
457	22,51,72,41	273.	66.
458	22,51,72,41	276.	68.
459	22,51,72,41	281.	66.
460	22,51,72,41	284.	67.
461	22,51,72,41	285.	69.
462	22,51,72,41	289.	70.
463	22,51,72,41	295.	67.
464	22,51,72,41	295.	70.
465	22,51,72,41	295.	69.
466	22,51,72,41	299.	71.
467	22,51,72,41	300.	70.
468	22,51,72,41	305.	72.
469	22,51,72,41	305.	73.
470	22,52,74,41	256.	64.
471	22,52,74,41	258.	64.
472	22,52,74,41	267.	66.
473	22,52,74,41	271.	66.
474	22,52,74,41	278.	66.
475	22,52,74,41	282.	67.
476	22,52,74,41	295.	70.
477	22,52,74,41	296.	71.

TABLE K2. (continued)

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	$/T DM Fed
478	22,52,74,41	298.	72.
479	22,52,74,41	302.	72.
480	22,52,74,41	305.	73.
481	22,52,74,41	316.	73.
482	23,52,74,41	256.	63.
483	23,52,74,41	263.	64.
484	23,52,74,41	267.	63.
485	23,52,74,41	272.	65.
486	23,52,74,41	274.	68.
487	23,52,74,41	274.	65.
488	23,52,74,41	275.	65.
489	23,52,74,41	280.	68.
490	23,52,74,41	283.	69.
491	23,52,74,41	283.	67.
492	23,52,74,41	283.	69.
493	23,52,74,41	291.	70.
494	23,52,74,41	294.	68.
495	23,52,74,41	295.	67.
496	23,52,74,41	305.	72.
497	23,52,74,41	311.	73.
498	23,52,73,41	257.	62.
499	23,52,73,41	263.	65.
500	23,52,73,41	267.	63.
501	23,52,73,41	277.	68.
502	23,52,73,41	278.	66.
503	23,52,73,41	278.	66.
504	23,52,73,41	283.	66.
505	23,52,73,41	292.	70.
506	23,52,73,41	295.	71.
507	21,52,72,41	258.	62.
508	21,52,72,41	260.	62.
509	21,52,72,41	267.	63.
510	21,52,72,41	268.	62.
511	21,52,72,41	271.	63.
512	21,52,72,41	290.	67.
513	21,52,72,41	292.	69.
514	21,52,72,41	297.	69.
515	21,52,72,41	298.	68.
516	21,52,72,41	299.	70.
517	21,52,72,41	317.	71.
518	21,52,72,41	319.	69.
519	21,52,72,41	355.	80.

TABLE K2. (continued)

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	$/T DM Fed
520	24,52,71,41	260.	64.
521	24,52,71,41	268.	66.
522	24,52,71,41	275.	66.
523	24,52,71,41	284.	69.
524	24,52,71,41	287.	68.
525	24,52,71,41	287.	67.
526	24,52,71,41	288.	69.
527	24,52,71,41	288.	70.
528	24,52,71,41	295.	69.
529	24,52,71,41	298.	71.
530	24,52,71,41	298.	69.
531	24,52,71,41	300.	71.
532	24,52,71,41	300.	73.
533	24,52,71,41	300.	72.
534	24,52,71,41	304.	75.
535	24,52,71,41	305.	72.
536	24,52,71,41	314.	72.
537	24,52,71,41	334.	74.
538	24,52,71,41	337.	75.
539	21,52,74,41	260.	63.
540	21,52,74,41	264.	64.
541	21,52,74,41	274.	64.
542	21,52,74,41	276.	66.
543	21,52,74,41	283.	69.
544	21,52,74,41	284.	67.
545	21,52,74,41	293.	65.
546	21,52,74,41	298.	70.
547	21,52,74,41	299.	69.
548	23,51,72,41	262.	64.
549	23,51,72,41	273.	66.
550	23,51,72,41	275.	66.
551	23,51,72,41	284.	69.
552	23,51,72,41	284.	69.
553	23,51,72,41	285.	68.
554	23,51,72,41	285.	69.
555	23,51,72,41	287.	67.
556	23,51,72,41	301.	70.
557	23,51,72,41	305.	72.
558	23,51,72,41	307.	74.
559	23,51,72,41	321.	71.
560	23,51,72,41	325.	75.

TABLE K2. (continued)

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	$/T DM Fed
561	23,52,71,41	262.	62.
562	23,52,71,41	271.	64.
563	23,52,71,41	274.	66.
564	23,52,71,41	276.	63.
565	23,52,71,41	277.	64.
566	23,52,71,41	281.	66.
567	23,52,71,41	281.	67.
568	23,52,71,41	283.	66.
569	23,52,71,41	283.	66.
570	23,52,71,41	284.	67.
571	23,52,71,41	301.	73.
572	24,52,72,41	263.	65.
573	24,52,72,41	269.	67.
574	24,52,72,41	294.	71.
575	24,52,72,41	296.	68.
576	24,52,72,41	298.	70.
577	24,52,72,41	298.	71.
578	24,52,72,41	304.	73.
579	24,52,72,41	313.	73.
580	24,52,72,41	321.	71.
581	24,52,72,41	373.	84.
582	24,52,74,41	263.	65.
583	24,52,74,41	273.	67.
584	24,52,74,41	278.	69.
585	24,52,74,41	279.	68.
586	24,52,74,41	281.	68.
587	24,52,74,41	285.	69.
588	24,52,74,41	286.	70.
589	24,52,74,41	287.	70.
590	24,52,74,41	287.	68.
591	24,52,74,41	295.	71.
592	24,52,74,41	296.	71.
593	24,52,74,41	299.	74.
594	24,52,74,41	299.	69.
595	24,52,74,41	311.	76.
596	24,52,74,41	312.	73.
597	24,52,74,41	319.	74.
598	24,52,74,41	330.	74.
599	21,52,73,41	265.	63.
600	21,52,73,41	267.	63.
601	21,52,73,41	273.	65.
602	21,52,73,41	278.	65.

TABLE K2. (continued)

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	$/T DM Fed
603	21,52,73,41	280.	67.
604	21,52,73,41	280.	65.
605	21,52,73,41	288.	69.
606	21,52,73,41	302.	71.
607	21,52,73,41	303.	68.
608	21,52,73,41	305.	71.
609	21,52,73,41	310.	72.
610	24,51,72,41	265.	64.
611	24,51,72,41	268.	66.
612	24,51,72,41	283.	67.
613	24,51,72,41	285.	68.
614	24,51,72,41	289.	69.
615	24,51,72,41	295.	72.
616	24,51,72,41	297.	73.
617	24,51,72,41	299.	72.
618	24,51,72,41	301.	72.
619	24,51,72,41	302.	71.
620	24,51,72,41	313.	76.
621	24,51,72,41	318.	77.
622	24,51,72,41	341.	78.
623	22,52,73,41	266.	64.
624	22,52,73,41	267.	64.
625	22,52,73,41	270.	66.
626	22,52,73,41	271.	66.
627	22,52,73,41	272.	68.
628	22,52,73,41	280.	66.
629	22,52,73,41	283.	69.
630	22,52,73,41	284.	67.
631	22,52,73,41	292.	68.
632	22,52,73,41	300.	69.
633	21,51,72,41	266.	63.
634	21,51,72,41	283.	66.
635	21,51,72,41	283.	67.
636	21,51,72,41	283.	67.
637	21,51,72,41	289.	68.
638	21,51,72,41	290.	68.
639	21,51,72,41	298.	70.
640	21,51,72,41	301.	71.
641	21,51,72,41	315.	74.
642	21,51,72,41	315.	72.
643	21,51,72,41	318.	73.
644	21,51,72,41	335.	77.
645	21,51,72,41	337.	72.

TABLE K2. (continued)

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	$/T DM Fed
646	22,51,71,41	268.	63.
647	22,51,71,41	281.	68.
648	22,51,71,41	282.	67.
649	22,51,71,41	284.	68.
650	22,51,71,41	288.	68.
651	22,51,71,41	291.	69.
652	22,51,71,41	302.	69.
653	22,51,71,41	303.	71.
654	22,51,71,41	303.	72.
655	22,51,71,41	304.	72.
656	22,51,71,41	312.	69.
657	22,51,71,41	323.	73.
658	22,51,71,41	330.	78.
659	21,52,71,41	270.	62.
660	21,52,71,41	275.	64.
661	21,52,71,41	277.	65.
662	21,52,71,41	283.	66.
663	21,52,71,41	283.	66.
664	21,52,71,41	285.	66.
665	21,52,71,41	294.	69.
666	21,52,71,41	303.	70.
667	21,52,71,41	316.	71.
668	21,51,71,41	272.	64.
669	21,51,71,41	275.	65.
670	21,51,71,41	276.	66.
671	21,51,71,41	294.	70.
672	21,51,71,41	298.	71.
673	21,51,71,41	315.	73.
674	21,51,71,41	334.	75.
675	23,51,74,41	273.	67.
676	23,51,74,41	287.	69.
677	23,51,74,41	288.	71.
678	23,51,74,41	293.	71.
679	23,51,74,41	306.	75.
680	23,51,74,41	306.	75.
681	23,51,74,41	350.	83.
682	23,51,74,41	353.	82.
683	24,52,73,41	273.	68.
684	24,52,73,41	276.	69.
685	24,52,73,41	283.	69.
686	24,52,73,41	288.	72.

TABLE K2. (continued)

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	$/T DM Fed
687	24,52,73,41	288.	70.
688	24,52,73,41	290.	70.
689	24,52,73,41	301.	72.
690	24,51,71,41	275.	68.
691	24,51,71,41	275.	68.
692	24,51,71,41	283.	68.
693	24,51,71,41	287.	69.
694	24,51,71,41	289.	70.
695	24,51,71,41	290.	69.
696	24,51,71,41	301.	74.
697	24,51,71,41	301.	72.
698	24,51,71,41	302.	68.
699	24,51,71,41	313.	74.
700	24,51,71,41	320.	76.
701	24,51,71,41	333.	80.
702	24,51,71,41	338.	77.
703	24,51,74,41	275.	68.
704	24,51,74,41	290.	70.
705	24,51,74,41	294.	73.
706	24,51,74,41	299.	75.
707	24,51,74,41	303.	72.
708	24,51,74,41	307.	74.
709	24,51,74,41	322.	80.
710	24,51,74,41	327.	80.
711	24,51,74,41	335.	82.
712	24,51,74,41	340.	78.
713	24,51,74,41	348.	86.
714	23,51,71,41	280.	65.
715	23,51,71,41	283.	68.
716	23,51,71,41	287.	69.
717	23,51,71,41	289.	69.
718	23,51,71,41	292.	70.
719	23,51,71,41	301.	72.
720	23,51,71,41	302.	71.
721	23,51,71,41	304.	74.
722	23,51,71,41	304.	72.
723	23,51,71,41	307.	73.
724	23,51,71,41	310.	72.
725	21,51,74,41	281.	67.
726	21,51,74,41	292.	70.
727	21,51,74,41	294.	69.
728	21,51,74,41	301.	72.
729	21,51,74,41	302.	72.

TABLE K2. (continued)

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	$/T DM Fed
730	21,51,74,41	305.	72.
731	21,51,74,41	311.	74.
732	21,51,74,41	312.	70.
733	21,51,74,41	314.	74.
734	21,51,74,41	317.	73.
735	21,51,74,41	317.	75.
736	21,51,74,41	319.	76.
737	21,51,74,41	321.	76.
738	21,51,74,41	330.	78.
739	21,51,74,41	354.	80.
740	22,51,73,41	283.	71.
741	22,51,73,41	304.	76.
742	22,51,73,41	305.	75.
743	22,51,73,41	308.	77.
744	22,51,73,41	323.	80.
745	22,51,73,41	327.	82.
746	22,51,73,41	331.	80.
747	22,51,73,41	333.	80.
748	22,51,73,41	334.	83.
749	22,51,73,41	350.	82.
750	22,51,73,41	361.	85.
751	22,51,73,41	363.	89.
752	22,51,74,41	283.	71.
753	22,51,74,41	285.	70.
754	22,51,74,41	285.	68.
755	22,51,74,41	287.	70.
756	22,51,74,41	300.	74.
757	22,51,74,41	304.	75.
758	22,51,74,41	308.	74.
759	22,51,74,41	316.	74.
760	22,51,74,41	318.	76.
761	22,51,74,41	328.	79.
762	22,51,74,41	331.	82.
763	21,51,71,42,82,89	291.	67.
764	21,51,71,42,82,89	324.	72.
765	21,51,71,42,82,89	427.	94.
766	21,51,73,41	306.	73.
767	21,51,73,41	324.	76.
768	21,51,73,41	340.	80.
769	21,41,73,41	341.	80.
770	21,51,73,41	345.	84.
771	21,51,73,41	350.	84.

TABLE K2. (continued)

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	$/T DM Fed
772	21,51,73,41	362.	85.
773	21,51,73,41	386.	92.
774	23,51,73,41	308.	76.
775	23,51,73,41	309.	76.
776	23,51,73,41	331.	79.
777	23,51,73,41	332.	78.
778	23,51,73,41	334.	80.
779	23,51,73,41	337.	81.
780	23,51,73,41	340.	82.
781	23,51,73,41	357.	85.
782	24,51,73,41	337.	81.
783	24,51,73,41	340.	80.
784	24,51,73,41	342.	83.
785	24,51,73,41	343.	82.
786	24,51,73,41	345.	83.
787	24,51,73,41	347.	83.
788	24,51,73,41	356.	86.
789	24,51,73,41	357.	89.
790	24,51,73,41	382.	92.
791	24,51,73,41	385.	89.
792	24,51,73,41	406.	97.

TABLE K3. FORAGE HANDLING SYSTEMS SIMULATED FOR 200 ACRES - PRE-CUT HARVESTING.

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
1	36,44,62,52,71,91,93,96,101,110	124.	28.
2	36,44,62,52,71,91,92,96,103,110	146.	32.
3	36,44,62,52,71,94,101,98,110	260.	54.
4	37,44,61,52,72,91,93,96,102,110	127.	29.
5	37,44,61,52,72,94,101,99,110	242.	51.
6	36,44,61,52,71,91,92,97,103,114	128.	29.
7	36,44,61,52,71,91,92,96,103,110	143.	34.
8	36,44,61,52,71,91,93,97,103,110	145.	33.
9	36,44,61,52,71,91,93,97,103,114	169.	38.
10	35,44,61,52,72,91,93,96,102,114	131.	29.
11	35,44,61,52,72,91,93,96,101,110	164.	36.
12	35,44,61,52,72,91,93,96,103,114	169.	34.
13	35,44,61,52,72,91,93,97,102,110	210.	45.
14	37,44,61,52,71,91,93,96,102,110	131.	30.
15	37,44,61,52,71,91,92,96,101,110	170.	37.
16	37,44,61,52,71,91,92,96,102,114	173.	37.
17	37,44,61,52,71,94,102,99,114	178.	40.
18	37,44,61,52,71,94,101,98,114	191.	43.
19	37,44,61,52,71,91,92,97,102,110	213.	44.
20	36,43,62,52,72,91,93,96,103,114	134.	32.
21	36,43,62,52,72,91,93,96,103,110	143.	32.
22	36,43,62,52,72,91,93,97,103,114	158.	35.
23	36,43,62,52,72,91,93,97,103,110	163.	36.
24	36,43,62,52,72,91,93,96,103,110	173.	37.
25	36,43,62,52,72,94,103,98,114	191.	42.
26	36,44,62,52,72,91,93,97,103,114	142.	32.
27	36,44,62,52,72,91,93,97,103,114	154.	35.
28	36,44,62,52,72,91,93,96,102,110	159.	36.
29	36,44,62,52,72,94,101,98,114	203.	47.
30	36,44,62,52,72,91,93,96,101,110	205.	43.
31	37,43,62,52,71,91,93,97,103,114	143.	32.
32	37,43,62,52,71,91,92,97,103,114	150.	34.
33	37,43,62,52,71,91,92,96,103,114	157.	35.
34	37,43,62,52,71,94,103,99,114	285.	55.
35	36,44,61,51,72,91,93,97,102,114	144.	33.
36	36,44,61,51,72,91,93,96,103,110	154.	34.
37	36,44,61,51,72,91,93,97,101,114	189.	41.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
38	35,43,61,52,72,91,93,96,103,110	154.	35.
39	35,43,61,52,72,91,93,96,103,110	162.	35.
40	35,43,61,52,72,94,103,99,110	222.	49.
41	35,43,61,52,72,94,103,99,114	237.	47.
42	36,44,62,51,71,91,92,97,102,114	155.	36.
43	36,44,62,51,71,91,93,97,102,110	164.	37.
44	36,44,62,51,71,91,92,96,101,114	186.	42.
45	36,44,62,51,71,94,102,98,114	212.	48.
46	36,44,62,51,71,91,92,97,101,114	216.	49.
47	36,43,62,51,71,91,92,96,103,110	156.	36.
48	36,43,62,51,71,91,93,96,103,110	211.	47.
49	36,43,62,51,71,94,103,98,110	247.	54.
50	36,43,62,51,71,94,103,98,110	273.	60.
51	36,43,62,51,71,94,103,98,110	278.	65.
52	36,44,63,52,72,91,93,97,102,114	157.	37.
53	36,44,63,52,72,91,93,96,103,110	172.	38.
54	36,44,63,52,72,91,93,96,101,110	173.	39.
55	36,44,63,52,72,91,93,97,101,110	206.	45.
56	36,44,63,52,72,91,93,97,102,110	239.	56.
57	36,44,63,52,72,94,101,98,114	246.	56.
58	36,44,63,52,72,94,102,98,110	273.	60.
59	37,43,62,51,71,91,93,97,103,110	157.	35.
60	37,43,62,51,71,91,93,96,103,110	222.	47.
61	37,43,62,51,71,94,103,98,110	291.	64.
62	37,43,61,52,71,91,92,96,103,114	159.	36.
63	37,43,61,52,71,94,103,98,114	175.	39.
64.	37,43,61,52,94,103,99,114	217.	47.
65	37,43,61,52,71,94,103,98,114	259.	54.
66	35,44,62,52,72,91,93,97,103,110	159.	33.
67	35,44,62,52,72,91,93,97,101,114	199.	42.
68	35,44,62,52,72,91,93,97,101,114	249.	51.
69	36,44,62,51,72,91,93,97,102,110	160.	36.
70	36,44,62,51,72,94,101,98,114	207.	48.
71	36,44,62,51,72,94,103,99,114	236.	54.
72	36,44,61,52,73,91,93,96,102,114	161.	38.
73	36,44,61,52,73,91,92,96,102,114	194.	45.
74	36,44,61,52,73,94,102,99,114	213.	48.
75	36,44,61,52,73,94,102,98,114	228.	48.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
76	36,43,61,52,72,91,93,97,103,110	165.	36.
77	36,43,61,52,72,94,103,98,114	181.	42.
78	36,43,61,52,72,94,103,99,110	213.	48.
79	36,43,61,52,72,94,103,99,114	256.	57.
80	37,43,61,52,72,91,93,97,103,114	167.	37.
81	37,43,61,52,72,91,93,96,103,114	199.	42.
82	37,43,61,52,72,94,103,98,114	220.	49.
83	37,43,61,52,72,94,103,99,114	229.	52.
84	36,44,61,51,71,91,92,96,103,114	168.	37.
85	36,44,61,51,71,91,92,97,103,114	175.	41.
86	36,44,61,51,71,91,93,96,101,114	203.	47.
87	36,44,61,51,71,91,93,97,101,114	207.	44.
88	36,44,61,51,71,91,93,97,102,114	221.	46.
89	36,44,61,51,71,94,103,98,110	253.	59.
90	36,44,61,51,71,94,101,99,114	256.	57.
91	37,44,63,52,72,91,93,96,101,110	169.	38.
92	37,44,63,52,72,94,103,98,114	208.	47.
93	37,44,63,52,72,91,93,97,103,114	230.	52.
94	37,44,63,52,72,94,102,99,110	312.	63.
95	37,44,62,51,71,91,92,97,101,110	170.	39.
96	37,44,62,51,71,91,93,97,103,114	226.	47.
97	36,43,61,51,71,91,93,97,103,110	171.	38.
98	36,43,61,51,71,91,92,97,103,110	221.	45.
99	36,43,61,51,71,94,103,98,114	238.	55.
100	36,43,61,51,71,94,103,98,110	279.	64.
101	35,44,61,51,71,94,103,99,114	174.	39.
102	35,44,61,51,71,94,103,98,110	237.	54.
103	35,44,61,51,71,91,92,96,102,110	254.	52.
104	37,44,63,52,71,91,92,96,102,110	174.	39.
105	37,44,63,52,71,91,92,97,102,114	185.	40.
106	37,44,63,52,71,94,103,99,114	254.	57.
107	37,44,63,52,71,91,93,97,102,114	273.	59.
108	36,43,62,51,72,91,93,97,103,110	174.	39.
109	36,43,62,51,72,94,103,99,110	244.	57.
110	36,43,62,51,72,94,103,98,110	285.	63.
111	37,44,62,52,73,91,92,97,101,110	176.	40.
112	37,44,62,52,73,91,92,97,102,110	218.	48.
113	37,44,62,52,73,94,101,98,114	218.	50.
114	37,44,62,52,73,94,103,99,110	265.	59.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
115	35,44,62,51,72,91,93,97,102,110	177.	39.
116	35,44,62,51,72,91,93,96,102,114	206.	44.
117	35,44,62,51,72,94,102,98,114	254.	55.
118	37,44,62,52,71,91,93,97,102,110	177.	40.
119	37,44,62,52,71,94,102,98,110	202.	45.
120	37,44,62,52,71,94,101,98,110	214.	46.
121	37,44,62,52,71,94,101,98,110	218.	49.
122	37,44,62,52,71,91,92,96,103,110	219.	42.
123	36,43,62,52,74,91,93,97,103,110	177.	42.
124	36,43,62,52,74,94,103,99,110	229.	52.
125	36,43,62,52,74,94,103,99,114	236.	53.
126	36,43,62,52,74,94,103,98,114	254.	54.
127	36,43,62,52,71,91,93,96,103,110	178.	37.
128	36,43,62,52,71,94,103,99,114	187.	42.
129	35,43,62,52,71,91,92,97,103,110	189.	41.
130.	36,43,62,52,71,94,103,98,110	252.	54.
131	36,43,62,52,71,94,103,98,110	255.	52.
132	37,43,62,51,72,91,93,97,103,114	178.	39.
133	37,43,62,51,72,91,93,96,103,114	206.	45.
134	37,43,62,51,72,94,103,98,114	238.	54.
135	37,43,62,51,72,94,103,99,114	266.	60.
136	37,43,62,51,72,94,103,98,114	308.	65.
137	37,43,62,51,72,94,103,99,110	338.	69.
138	36,43,61,52,71,91,92,96,103,110	178.	39.
139	36,43,61,52,71,94,103,99,110	193.	45.
140	36,43,61,52,71,94,103,98,114	244.	53.
141	36,43,61,52,71,94,103,98,110	278.	60.
142	37,44,62,52,74,91,93,97,102,114	178.	41.
143	37,44,62,52,74,94,102,99,114	219.	49.
144	37,44,62,52,74,94,103,99,114	235.	53.
145	37,44,62,52,74,94,103,99,114	247.	52.
146	35,44,61,51,72,91,93,97,103,110	179.	39.
147	35,44,61,51,72,91,93,97,103,114	204.	43.
148	35,44,61,51,72,91,93,97,101,114	211.	46.
149	35,44,61,51,72,91,93,96,101,114	217.	46.
150	30,33,44,61,52,71,91,93,97,102,114	180.	40.
151	30,33,44,61,62,71,94,102,98,114	237.	48.
152	35,43,62,52,71,91,93,96,103,114	182.	39.
153	35,43,62,52,71,91,93,96,103,114	215.	46.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DN Fed
154	35,44,61,52,71,91,92,96,101,114	183.	40.
155	35,44,61,52,71,91,93,97,101,114	199.	44.
156	35,44,61,52,71,94,102,99,110	216.	47.
157	35,44,61,52,71,91,93,97,103,114	219.	47.
158	37,44,61,51,72,91,93,97,101,110	183.	40.
159	37,44,61,51,72,91,93,97,101,110	218.	51.
160	37,44,61,51,72,94,101,98,110	272.	61.
161	37,44,61,51,72,94,103,98,110	273.	62.
162	37,44,61,51,72,91,93,97,103,114	276.	60.
163	36,44,62,52,74,91,93,96,103,110	184.	41.
164	36,44,62,52,74,91,93,96,101,114	185.	42.
165	36,44,62 ,74,94,103,99,114	234.	54.
166	36,44,62,52,74,94,103,99,114	237.	55.
167	36,44,62,52,74,94,102,99,110	244.	56.
168	37,43,61,51,72,91,93,96,103,110	186.	40.
169	35,44,62,52,73,91,92,97,102,114	186.	43.
170	35,44,62,52,73,91,93,96,102,110	196.	44.
171	35,44,62,52,73,91,92,97,103,114	222.	48.
172	35,44,62,52,73,94,103,98,110	317.	71.
173	36,43,61,51,72,91,93,96,103,114	186.	41.
174	36,43,61,51,72,94,103,98,114	227.	52.
175	36,43,61,51,72,94,103,99,110	228.	52.
176	36,43,61,51,72,94,103,98,110	281.	60.
177	36,43,61,51,72,94,103,98,110	282.	65.
178	36,43,61,51,72,94,103,99,110	304.	66.
179	36,44,63,52,71,91,93,96,102,114	187.	44.
180	36,44,63,52,71,91,92,97,101,114	216.	49.
181	36,44,63,52,71,94,103,99,114	242.	55.
182	36,44,63,52,71,94,102,99,110	262.	61.
183	30,34,44,61,52,74,91,93,96,103,110	188.	41.
184	30,34,44,61,52,74,91,93,96,101,110	244.	53.
185	30,34,44,61,52,74,94,103,98,114	276.	56.
186	37,43,62,52,72,91,93,96,103,114	188.	41.
187	37,43,62,52,72,94,103,98,114	198.	41.
188	37,43,62,52,72,94,103,98,114	222.	48.
189	37,43,62,52,72,94,103,98,114	227.	52.
190	30,34,43,61,52,71,91,92,96,103,114	189.	41.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
191	35,43,61,52,71,91,92,97,103,114	189.	41.
192	35,43,61,52,71,91,93,96,103,114	218.	48.
193	35,43,61,52,71,91,93,97,103,114	273.	53.
194	35,43,61,52,73,91,93,97,103,114	189.	43.
195	35,43,61,52,73,94,103,99,110	229.	54.
196	36,43,61,52,73,94,103,99,110	233.	53.
197	36,43,61,52,73,91,92,96,103,114	234.	53.
198	30,33,43,61,52,71,91,92,96,103,114	189.	38.
199	30,33,43,61,52,71,91,93,97,103,114	194.	42.
200	30,33,43,61,52,71,91,93,96,103,114	209.	43.
201	30,33,43,61,52,71,94,103,99,110	227.	47.
202	30,33,43,61,52,71,94,103,99,114	248.	52.
203	30,33,43,61,52,71,94,103,99,114	323.	58.
204	30,34,44,61,52,72,91,93,96,103,114	191.	38.
205	31,34,44,62,52,71,91,93,96,102,110	191.	43.
206	31,34,44,62,52,71,94,101,98,114	239.	49.
207	30,33,44,62,52,72,91,93,96,102,110	191.	41.
208	30,33,44,62,52,72,94,103,99,114	196.	43.
209	36,44,61,52,74,91,93,96,101,110	192.	44.
210	36,44,61,52,74,94,103,98,114	262.	62.
211	35,44,62,52,74,91,93,97,103,110	192.	42.
212	36,44,62,52,74,94,103,99,114	235.	52.
213	36,43,62,52,73,91,92,96,103,110	192.	44.
214	36,43,62,52,73,91,93,96,103,110	194.	42.
215	36,43,62,52,73,91,92,96,103,114	198.	46.
216	36,43,62,52,73,91,93,96,103,110	214.	47.
217	37,43,61,52,73,91,92,97,103,114	195.	43.
218	37,43,61,52,73,91,92,96,103,110	198.	46.
219	37,43,61,52,73,91,93,97,103,114	205.	45.
220	37,43,61,52,73,94,103,99,110	267.	61.
221	37,43,61,52,73,94,103,99,114	275.	65.
222	37,43,61,52,73,94,103,98,114	288.	62.
223	37,43,61,52,73,91,93,97,103,114	289.	63.
224	37,43,61,52,73,94,103,98,114	305.	63.
225	35,43,61,52,74,94,103,99,110	198.	45.
226	35,43,61,52,74,91,93,97,103,110	209.	47.
227	35,43,61,52,74,91,93,97,103,110	211.	48.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
228	35,43,61,52,74,91,93,97,103,110	229.	50.
229	35,43,61,52,74,94,103,98,110	278.	59.
230	35,43,61,52,74,91,93.97,103,110	300.	64.
231	36,44,61,52,72,94,101,98,110	199.	45.
232	31,33,43,61,52,72,91,93,97,103,110	199.	42.
233	31,33,43,61,52,72,94,103,99,114	269.	54.
234	31,33,43,61,52,72,94,103,98,114	312.	62.
235	35,43,63,52,71,91,92,96,103,114	200.	45.
236	36,43,62,52,71,94,103,99,114	290.	64.
237	35,43,63,52,71,94,103,99,110	291.	65.
238	31,34,43,62,52,72,91,93,97,103,110	200.	43.
239	31,34,43,62,52,72,91,93,97,103,114	209.	43.
240	31,34,43,62,52,72,94,103,99,114	249.	53.
241	31,34,43,62,52,72,94,103,99,114	264.	55.
242	37,44,63,51,72,91,93,96,102,110	201.	46.
243	37,44,63,51,72,94,102,99,110	372.	80.
244	36,44,62,52,73,91,92,97,102,110	202.	47.
245	35,44,62,52,71,91,93,96,102,110	203.	43.
246	30,33,44,61,52,72,91,93,97,103,110	203.	41.
247	35,44,61,52,74,94,103,98,114	205.	47.
248	35,44,61,52,74,91,93,96,101,114	207.	46.
249	31,34,44,62,51,72,91,93,96,102,110	205.	45.
250	31,34,44,62,51,72,91,93,96,102,114	228.	48.
251	31,34,44,62,51,72,91,93,96,103,110	234.	48.
252	31,33,43,61,52,71,91,92,96,103,114	206.	44.
253	31,33,43,61,52,71,91,93,96,103,110	228.	49.
254	31,33,43,61,52,71,94,103,98,114	266.	56.
255	37,43,62,52,74,94,103,98,110	206.	47.
256	37,43,62,52,74,91,93,96,103,114	210.	45.
257	37,43,62,52,74,94,103,98,114	243.	57.
258	37,43,62,52,74,94,103,98,110	249.	59.
259	30,33,44,61,51,72,91,93,97,102,114	207.	44.
260	30,33,44,61,51,72,94,103,98,114	234.	50.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
261	37,44,63,52,73,91,93,96,102,114	207.	47.
262	37,44,63,52,73,91,93,97,102,114	293.	63.
263	37,44,63,52,73,94,102,98,110	307.	66.
264	37,44,63,52,73,94,102,99,114	370.	78.
265	36,43,63,52,71,91,92,103,110	208.	45.
266	36,43,63,52,71,94,103,99,110	245.	53.
267	36,43,63,52,71,94,103,98,110	265.	58.
268	36,43,63,52,71,94,103,98,110	290.	67.
269	37,43,62,52,73,94,103,99,114	209.	47.
270	37,43,62,52,73,91,93,96,103,114	234.	53.
271	37,43,62,52,73,91,93,96,103,114	250.	58.
272	30,34,43,62,52,71,91,93,97,103,114	210.	46.
273	30,34,43,62,52,71,91,93,97,103,114	228.	45.
274	30,34,43,62,52,71,91,93,96,103,110	243.	51.
275	30,34,43,62,52,71,94,103,99,114	246.	51.
276	35,43,62,52,73,91,93,97,103,114	210.	47.
277	35,43,62,52,73,91,93,97,103,110	220.	49.
278	35,43,62,52,73,91,92,96,103,110	223.	47.
279	35,43,62,52,73,91,92,97,103,114	234.	51.
280	35,43,62,52,73,94,103,98,110	252.	58.
281	30,33,44,61,52,73,91,92,103,110	211.	46.
282	30,33,44,61,52,73,94,101,98,114	304.	60.
283	35,43,61,51,72,91,93,97,103,110	212.	44.
284	35,43,61,51,72,91,93,96,103,114	254.	50.
285	35,43,61,51,72,94,103,98,110	267.	57.
286	31,33,44,61,52,71,91,93,96,102,110	213.	43.
287	31,33,44,61,52,71,94,101,98,110	287.	62.
288	31,33,44,61,52,73,91,93,96,102,110	213.	47.
289	30,34,44,62,51,71,91,93,97,102,110	213.	46.
290	36,43,61,52,74,91,93,97,103,114	213.	50.
291	36,43,61,52,74,94,103,98,110	232.	53.
292	31,33,44,61,52,72,94,101,98,114	215.	45.
293	31,33,44,61,52,72,94,103,99,110	276.	55.
294	35,44,61,51,73,91,92,97,103,110	216.	49.
295	36,44,61,51,73,94,101,99,114	330.	73.
296	30,34,44,61,52,73,91,93,96,101,114	217.	49.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
297	35,44,63,52,71,91,92,96,101,110	218.	50.
298	35,44,63,52,71,91,92,97,101,114	245.	50.
299	35,44,63,52,71,94,102,99,110	278.	61.
300	30,33,43,62,51,72,91,93,97,103,114	218.	45.
301	30,33,43,62,51,72,91,93,97,103,110	239.	52.
302	31,34,43,61,52,74,91,93,96,103,110	219.	48.
303	37,43,63,51,72,91,93,97,103,114	219.	48.
304	37,43,63,51,72,91,93,97,103,110	238.	55.
305	37,43,63,51,72,91,93,96,103,114	264.	55.
306	30,34,43,62,52,72,91,93,96,103,114	220.	43.
307	30,33,43,62,52,71,91,93,97,103,114	221.	49.
308	30,33,43,62,52,71,94,103,98,114	235.	51.
309	30,33,43,62,52,71,94,103,99,114	281.	57.
310	30,33,43,61,52,72,91,93,97,103,110	221.	44.
311	37,44,62,51,72,91,93,96,102,110	222.	47.
312	37,44,62,51,72,94,101,98,110	246.	55.
313	37,44,62,51,72,94,102,99,114	272.	62.
314	37,43,61,51,71,91,93,96,103,114	223.	47.
315	37,43,63,52,71,91,92,96,103,110	223.	51.
316	37,43,63,52,71,94,103,99,110	290.	67.
317	37,43,63,52,71,94,103,98,110	328.	69.
318	37,43,63,52,71,94,103,98,114	356.	68.
319	37,43,63,52,71,94,103,98,110	371.	76.
320	37,43,63,51,71,91,93,97,103,110	223.	51.
321	37,43,63,51,71,91,93,97,103,114	251.	56.
322	37,43,63,51,71,91,92,96,103,114	262.	58.
323	37,43,63,51,71,94,103,98,114	290.	62.
324	31,33,43,61,51,72,91,93,97,103,114	224.	48.
325	31,33,43,61,51,72,94,103,99,114	327.	66.
326	31,33,44,61,52,74,91,93,96,101,110	224.	48.
327	31,33,44,61,52,74,91,93,97,102,114	231.	48.
328	31,33,44,61,52,74,94,102,98,114	271.	53.
329	37,44,61,52,73,91,93,97,101,110	224.	51.
330	37,44,61,52,73,94,101,99,110	290.	67.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
331	30,34,43,61,52,73,94,103,98,114	225.	49.
332	37,44,61,52,74,91,93,96,101,114	225.	50.
333	37,44,61,52,74,94,103,99,110	259.	61.
334	37,44,61,52,74,94,101,98,110	277.	58.
335	31,34,43,62,51,71,91,93,97,103,110	226.	49.
336	31,34,43,62,51,71,94,103,99,114	264.	55.
337	31,34,43,62,51,71,94,103,98,110	300.	63.
338	30,33,44,61,52,74,91,93,97,103,114	227.	47.
339	30,33,44,61,52,74,94,103,99,114	242.	53.
340	30,33,44,61,52,74,91,93,97,103,114	243.	55.
341	30,33,44,61,52,74,94,103,99,114	266.	58.
342	30,33,44,61,52,74,94,103,98,114	266.	54.
343	30,33,44,61,52,74,94,103,99,110	362.	69.
344	30,34,44,63,52,71,91,93,96,103,114	227.	47.
345	30,33,44,62,51,72,91,93,96,103,114	227.	49.
346	30,33,44,62,51,72,91,93,97,101,114	243.	52.
347	30,33,44,62,51,72,94,102,98,110	296.	65.
348	35,43,62,51,71,91,93,96,103,110	228.	47.
349	30,34,43,63,52,72,91,93,96,103,110	229.	51.
350	30,34,43,63,52,72,94,103,98,114	299.	64.
351	30,34,43,63,52,72,94,103,99,110	439.	79.
352	35,43,61,51,71,91,92,96,103,114	229.	50.
353	35,43,61,51,71,94,103,99,114	268.	58.
354	35,43,61,51,71,94,103,98,114	319.	67.
355	35,43,62,52,74,91,93,97,103,110	230.	50.
356	35,43,62,52,74,91,93,96,103,110	239.	50.
357	35,43,62,52,74,94,103,99,114	257.	56.
358	35,44,61,52,73,94,101,98,114	230.	49.
359	35,44,61,52,73,94,102,98,114	247.	51.
360	35,44,61,52,73,94,101,98,110	262.	57.
361	37,43,61,51,74,91,93,96,103,110	230.	54.
362	37,43,61,51,74,91,93,96,103,114	241.	56.
363	37,43,61,51,74,91,93,97,103,110	248.	57.
364	37,43,61,51,74,91,93,96,103,110	270.	60.
365	37,43,61,51,74,91,93,97,103,114	294.	63.
366	37,43,61,51,74,91,93,96,103,114	299.	63.
367	37,43,61,51,74,94,103,98,110	300.	71.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	Total cost (nearest $) $/T DM Fed
368	37,43,61,51,74,91,93,97,103,114	304.	61.
369	37,43,61,51,73,91,93,97,103,110	340.	76.
370	37,43,61,51,74,94,103,99,110	350.	81.
371	37,43,61,51,74,94,103,99,110	368.	84.
372	37,43,61,51,74,94,103,98,110	416.	86.
373	30,34,44,62,52,74,91,93,97,103,114	230.	46.
374	30,34,44,62,52,74,94,102,99,114	269.	59.
375	30,34,44,62,52,74,94,103,98,114	347.	70.
376	36,44,61,51,74,91,93,97,102,110	230.	51.
377	36,44,61,51,74,91,93,97,101,110	259.	58.
378	36,44,61,51,74,94,101,99,114	323.	76.
379	30,33,43,61,51,71,91,92,97,103,114	231.	48.
380	30,34,43,62,52,74,91,93,96,103,114	231.	48.
381	30,34,43,62,52,74,91,93,96,103,114	236.	51.
382	30,34,43,62,52,74,91,93,97,103,110	298.	61.
383	30,34,43,62,52,74,91,93,96,103,114	302.	58.
384	30,34,43,62,52,74,94,103,98,110	311.	63.
385	31,34,43,61,52,71,91,92,96,103,114	233.	47.
386	31,34,43,61,52,71,94,103,98,114	238.	51.
387	31,34,43,61,52,71,94,103,98,114	311.	66.
388	31,34,44,61,52,71,94,103,99,114	235.	50.
389	31,34,43,62,51,72,91,93,97,103,110	236.	49.
390	31,34,43,62,51,72,94,103,99,110	327.	72.
391	35,44,61,51,74,91,93,97,102,114	237.	54.
392	35,44,61,51,74,94,102,98,110	373.	81.
393	36,43,61,51,74,91,93,96,103,110	238.	55.
394	36,43,61,51,73,91,93,97,103,110	255.	55.
395	36,43,61,51,74,94,103,99,114	334.	72.
396	36,43,61,51,74,94,103,98,110	338.	71.
397	36,43,61,51,74,94,103,98,110	358.	81.
398	36,43,61,51,74,94,103,98,114	374.	80.
399	31,34,44,61,51,71,91,92,97,101,110	239.	49.
400	30,34,44,61,51,72,91,93,96,101,110	240.	53.
401	35,44,63,52,72,94,103,98,114	240.	54.
402	35,44,63,52,72,94,103,98,110	284.	65.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
403	36,43,63,52,72,94,103,98,110	240.	55.
404	36,43,63,52,72,91,93,96,103,110	249.	58.
405	36,43,63,52,72,94,103,99,114	297.	64.
406	37,44,62,51,74,91,93,97,103,114	241.	56.
407	37,44,62,51,73,91,93,97,103,114	263.	61.
408	37,44,62,51,74,91,93,96,102,114	270.	63.
409	35,43,63,52,72,91,93,97,103,114	242.	52.
410	35,43,63,52,72,94,103,98,110	267.	59.
411	35,43,63,52,72,91,93,97,103,114	297.	60.
412	31,34,44,61,51,72,91,93,96,102,110	243.	50.
413	31,33,44,62,51,71,91,93,97,101,110	243.	50.
414	31,33,44,62,51,71,94,103,98,110	324.	66.
415	30,34,44,62,52,73,91,92,97,102,114	246.	54.
416	31,34,44,63,52,71,91,92,96,102,110	247.	51.
417	37,43,63,52,72,94,103,99,114	247.	55.
418	37,43,63,52,72,94,103,99,110	253.	58.
419	37,43,63,52,72,91,93,96,103,110	256.	55.
420	37,43,63,52,72,94,103,98,110	258.	59.
421	37,43,63,52,72,94,103,98,114	319.	73.
422	37,44,63,51,71,91,92,96,101,114	248.	55.
423	37,44,63,51,71,91,92,97,101,114	324.	67.
424	30,34,44,61,52,71,94,101,98,110	248.	52.
425	30,34,44,61,52,71,94,103,98,110	253.	54.
426	35,44,62,51,71,94,101,99,114	248.	57.
427	35,44,62,51,71,94,102,99,110	258.	57.
428	35,44,62,51,71,94,102,99,110	292.	62.
429	35,44,62,51,71,91,93,96,101,110	293.	60.
430	36,44,63,52,73,94,103,98,114	248.	57.
431	36,44,63,52,73,91,93,97,102,110	254.	57.
432	36,44,63,52,73,94,103,99,114	262.	58.
433	36,44,63,52,73,91,92,97,103,114	283.	64.
434	36,44,63,52,73,91,93,97,101,114	325.	73.
435	36,44,63,52,73,94,103,98,110	368.	80.
436	31,34,44,61,52,72,94,102,99,110	248.	54.
437	31,34,44,61,52,72,94,102,99,110	251.	56.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
438	37,43,62,51,74,91,93,97,103,114	248.	54.
439	30,34,43,63,52,71,91,93,96,103,110	249.	53.
440	30,34,43,63,52,71,94,103,98,110	319.	69.
441	30,34,43,63,52,71,94,103,98,114	359.	70.
442	30,34,44,62,52,71,94,101,99,114	249.	51.
443	35,44,63,51,71,91,92,97,102,114	350.	54.
444	35,44,63,51,71,94,102,99,114	300.	66.
445	36,44,63,52,74,91,93,97,102,110	253.	55.
446	36,44,63,52,74,91,93,97,102,114	283.	63.
447	36,44,63,52,74,94,101,98,110	340.	78.
448	35,43,62,52,72,94,103,99,110	253.	54.
449	35,43,62,52,72,94,103,98,114	266.	50.
450	37,44,61,51,73,91,92,97,101,114	253.	57.
451	37,44,61,51,73,94,101,98,114	274.	65.
452	37,44,61,51,73,91,92,96,102,114	298.	66.
453	37,44,61,51,73,94,103,98,114	320.	74.
454	31,34,44,63,52,72,91,93,97,101,114	254.	54.
455	31,34,44,63,52,72,94,103,99,110	321.	71.
456	31,34,43,63,51,72,91,93,97,103,114	255.	53.
457	36,43,61,51,73,91,92,96,102,114	256.	57.
458	36,43,61,51,73,91,93,97,103,110	260.	61.
459	36,43,61,51,73,91,92,97,103,114	315.	71.
460	36,43,61,51,73,91,92,96,103,110	321	67.
461	36,43,61,51,73,94,103,99,114	401.	87.
462	30,33,44,63,52,71,91,92,96,103,110	256.	55.
463	30,33,44,63,52,71,91,93,96,101,110	269.	55.
464	30,33,44,63,52,71,94,101,98,110	307.	67.
465	30,33,44,63,52,71,91,93,97,101,110	324.	65.
466	30,33,44,63,52,71,94,101,98,110	349.	75.
467	30,33,44,63,52,71,93,103,98,110	374.	76.
468	35,44,63,51,72,94,101,99,114	257.	57.
469	35,44,63,51,72,91,93,97,101,110	274.	60.
470	35,44,63,51,72,94,103,98,110	280.	60.
471	35,44,63,51,72,94,103,99,114	305.	65.
472	35,44,63,51,72,94,102,99,114	340.	72.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
473	30,33,44,63,51,71,91,92,96,101,114	258.	57.
474	30,33,44,63,51,71,91,92,96,103,110	272.	58.
475	30,33,44,63,52,73,91,93,96,103,114	259.	55.
476	31,34,44,61,52,73,94,102,98,114	259.	59.
477	35,43,61,52,73,94,103,99,110	260.	58.
478	35,43,61,52,73,94,103,99,110	326.	70.
479	35,43,61,51,73,91,93,97,103,114	260.	58.
480	36,43,61,51,73,91,92,96,103,110	309.	68.
481	35,43,61,51,73,94,103,99,114	348.	79.
482	35,43,61,51,73,94,103,98,110	350.	67.
483	35,43,61,51,73,94,103,99,110	350.	79.
484	35,43,61,51,73,94,103,98,114	449.	100.
485	31,33,44,63,52,71,91,93,97,101,110	261.	55.
486	31,33,44,63,52,71,91,92,97,103,110	263.	55.
487	31,33,44,63,52,71,94,103,99,110	330.	68.
488	30,34,43,61,51,72,94,103,98,110	261.	52.
489	30,34,43,61,51,72,94,103,98,114	289.	59.
490	36,43,63,51,71,91,92,96,103,114	262.	58.
491	36,43,63,51,71,94,103,98,110	325.	74.
492	31,34,43,63,52,71,94,103,99,114	262.	60.
493	31,34,43,63,52,71,94,103,99,114	366.	78.
494	37,44,62,52,72,94,102,99,110	263.	56.
495	35,44,63,52,73,91,92,96,103,114	264.	58.
496	35,44,63,52,73,91,92,97,101,110	270.	62.
497	35,44,63,52,73,94,102,98,114	294.	63.
498	35,44,63,52,73,94,101,98,114	338.	69.
499	35,44,63,52,73,94,103,98,114	343.	73.
500	35,43,63,52,74,91,93,97,103,114	265.	60.
501	35,43,63,52,74,91,93,96,103,110	301.	68.
502	35,43,63,52,74,91,93,97,103,110	304.	65.
503	35,43,63,52,74,94,103,99,110	315.	70.
504	35,43,63,52,74,91,93,96,103,110	324.	71.
505	35,43,63,52,74,94,103,98,110	389.	82.
506	31,34,44,61,52,74,91,93,96,101,114	266.	59.
507	31,34,44,61,52,74,94,101,99,110	284.	59.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
508	35,44,63,52,74,94,101,99,114	266.	60.
509	35,44,63,52,74,91,93,96,102,114	271.	61.
510	30,34,44,62,52,72,94,102,99,110	266.	55.
511	31,33,43,61,52,73,94,103,99,114	267.	60.
512	31,33,43,62,52,74,94,103,99,114	267.	61.
513	31,33,43,62,52,74,91,93,97,103,114	285.	62.
514	37,43,63,52,73,91,93,97,103,110	268.	59.
515	37,43,63,52,73,91,92,97,103,114	275.	64.
516	36,43,63,52,73,94,103,99,114	269.	62.
517	36,43,63,52,73,94,103,98,114	288.	65.
518	36,43,63,52,73,94,103,98,114	327.	74.
519	36,43,63,52,73,94,103,98,114	343.	80.
520	31,34,43,62,52,71,94,103,98,114	269.	56.
521	31,34,43,62,52,71,94,103,99,114	270.	55.
522	36,44,63,51,73,91,93,97,102,110	271.	62.
523	36,44,63,51,73,91,93,97,102,110	272.	62.
524	36,44,63,51,73,94,102,99,114	408.	93.
525	37,44,62,51,73,91,93,97,102,110	272.	61.
526	37,44,62,51,73,91,93,96,102,114	377.	70.
527	31,33,44,63,51,71,91,92,97,101,114	273.	59.
528	31,33,44,63,51,71,94,102,98,110	366.	79.
529	31,33,44,63,51,71,94,103,99,110	390.	82.
530	36,44,63,51,74,91,93,97,103,110	273.	63.
531	31,33,44,63,52,73,91,93,96,103,114	273.	57.
532	37,44,61,51,74,91,93,97,101,114	274.	58.
533	37,44,61,51,74,94,102,99,114	302.	69.
534	37,44,61,51,74,94,101,98,110	342.	77.
535	30,33,44,62,52,74,94,102,99,110	274.	61.
536	30,33,44,62,52,74,94,102,98,114	304.	63.
537	37,43,61,52,74,91,93,96,103,110	275.	53.
538	37,43,61,52,74,91,93,97,103,110	282.	57.
539	35,44,62,51,73,91,93,96,102,114	277.	61.
540	35,44,62,51,73,91,93,96,101,110	358.	74.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
541	35,44,62,51,73,94,101,99,110	400.	86.
542	35,44,62,51,73,94,102,99,114	442.	97.
543	30,34,43,62,51,71,91,92,97,103,114	277.	61.
544	37,43,63,52,74,94,103,99,114	278.	63.
545	37,43,63,52,74,94,103,99,110	354.	79.
546	37,43,63,52,74,94,103,98,110	398.	85.
547	37,44,61,51,71,94,103,98,110	278.	61.
548	31,33,43,62,51,72,94,103,99,110	279.	56.
549	31,33,43,62,51,72,94,103,99,114	310.	64.
550	31,34,44,62,52,73,94,103,99,110	279.	60.
551	30,33,44,62,52,73,94,103,98,110	279.	62.
552	30,34,44,63,51,71,91,93,96,103,110	280.	58.
553	31,34,44,61,51,73,91,92,96,103,110	280.	64.
554	31,34,44,61,51,73,91,93,96,103,114	307.	67.
555	31,34,44,61,51,73,94,102,98,110	407.	88.
556	30,33,43,62,52,72,94,103,98,110	281.	57.
557	36,43,63,52,74,91,93,96,103,110	281.	59.
558	36,43,63,52,74,94,103,99,110	308.	70.
559	36,43,63,52,74,94,103,98,114	350.	79.
560	36,43,63,52,74,94,103,98,114	419.	80.
561	30,33,43,61,51,72,94,103,99,114	282.	60.
562	36,43,62,51,74,94,103,99,114	282.	62.
563	36,43,62,51,74,94,103,99,114	316.	73.
564	36,43,62,51,74,94,103,99,110	356.	81.
565	37,44,63,52,74,94,102,99,110	282.	65.
566	37,44,63,52,74,91,93,96,102,114	314.	69.
567	37,44,63,52,74,94,101,98,114	315.	72.
568	37,44,63,52,74,94,103,99,110	317.	74.
569	37,44,63,52,74,94,101,99,110	402.	85.
570	31,34,43,62,52,73,91,93,97,103,110	282.	64.
571	31,34,43,62,52,73,94,103,99,110	349.	71.
572	30,33,43,62,51,74,91,93,97,103,114	283.	64.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
573	31,34,44,63,51,72,91,93,96,102,110	284.	60.
574	31,34,44,63,51,72,94,101,98,110	362.	77.
575	31,33,44,62,51,74,91,93,97,103,114	284.	62.
576	31,33,44,62,51,74,94,101,98,110	463.	104.
577	31,33,44,62,51,74,94,102,98,114	475.	104.
578	35,43,61,51,74,91,93,97,102,110	284.	60.
579	35,43,61,51,74,94,103,99,110	316.	70.
580	35,43,61,51,74,91,93,96,103,114	337.	71.
581	35,43,61,51,74,94,103,98,110	447.	91.
582	36,44,63,51,72,94,102,98,114	284.	63.
583	36,44,63,51,72,94,101,99,110	325.	72.
584	36,44,63,51,72,94,103,99,110	330.	73.
585	30,34,43,62,52,73,91,93,96,103,110	285.	59.
586	35,43,63,52,73,91,93,96,103,114	286.	66.
587	35,43,63,52,73,94,103,99,114	300.	67.
588	30,33,44,62,51,71,94,103,99,114	286.	64.
589	30,33,43,61,52,74,94,103,99,114	287.	61.
590	30,33,43,61,52,74,94,103,99,114	351.	70.
591	36,44,62,51,74,91,93,97,101,110	290.	67.
592	36,44,62,51,74,94,101,99,110	313.	72.
593	36,44,62,51,74,94,102,98,114	473.	101.
594	36,43,63,51,74,91,93,96,103,114	290.	66.
595	36,43,63,51,74,91,93,97,103,114	346.	73.
596	36,43,63,51,74,91,93,96,103,114	355.	77.
597	36,43,63,51,74,94,103,99,110	501.	107.
598	30,33,44,63,52,74,91,93,97,101,110	291.	60.
599	31,34,43,61,51,73,91,92,97,103,110	291.	64.
600	31,34,43,61,51,73,91,92,97,103,110	330.	70.
601	35,44,62,51,74,91,93,97,102,114	291.	60.
602	35,44,62,51,74,94,101,98,110	358.	81.
603	35,43,62,51,73,91,93,97,103,114	293.	63.
604	35,43,62,51,73,91,93,97,103,114	314.	66.
605	35,43,62,51,73,94,103,98,110	393.	90.
606	31,33,43,61,52,74,91,93,97,103,110	294.	62.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
607	37,43,61,51,73,91,92,96,103,114	296.	65.
608	37,43,61,51,73,94,103,99,110	394.	93.
609	36,43,63,51,73,91,92,96,103,110	297.	70.
610	36,43,63,51,73,91,92,97,103,114	304.	69.
611	36,43,63,51,73,94,103,99,110	335.	75.
612	36,43,63,51,73,91,93,96,103,110	336.	79.
613	36,43,63,51,73,91,92,97,103,114	342.	73.
614	36,43,63,51,73,94,103,98,110	446.	97.
615	30,34,43,63,51,71,91,93,97,103,110	299.	64.
616	35,43,63,51,72,91,93,96,103,114	299.	64.
617	35,43,63,51,72,94,103,98,110	313.	68.
618	35,43,63,51,72,91,93,97,103,114	320.	63.
619	35,43,63,51,72,94,103,98,114	332.	74.
620	35,43,63,51,72,91,93,97,103,114	341.	68.
621	35,43,63,51,72,94,103,99,114	393.	83.
622	31,33,44,62,51,72,94,103,99,110	300.	64.
623	30,34,43,61,52,72,94,103,99,114	300.	64.
624	30,33,44,61,51,74,91,93,97,103,114	301.	61.
625	30,33,44,61,51,74,94,103,99,114	326.	71.
626	30,33,44,61,51,74,91,93,97,101,110	369.	77.
627	31,34,44,63,51,71,91,92,97,103,110	302.	62.
628	31,34,44,63,51,71,91,92,97,102,114	337.	64.
629	31,34,44,63,51,71,94,102,99,114	372.	74.
630	31,33,43,63,51,71,91,93,97,103,110	302.	65.
631	31,33,43,63,51,71,94,103,99,114	330.	70.
632	31,33,43,63,51,71,94,103,99,114	392.	84.
633	31,33,43,61,51,71,91,93,96,103,110	303.	62.
634	31,34,44,62,51,71,94,101,98,114	303.	63.
635	31,34,44,62,51,71,94,103,98,110	305.	66.
636	30,33,43,61,51,73,91,92,97,103,114	304.	65.
637	30,33,43,61,51,73,91,92,96,103,114	318.	69.
638	30,33,43,61,51,73,91,92,97,103,110	324.	72.
639	30,33,43,61,51,73,94,102,99,110	460.	95.
640	31,34,43,62,51,73,91,93,97,103,110	306.	66.
641	31,34,43,62,51,73,91,93,97,103,110	330.	73.
642	31,34,43,62,51,73,94,103,99,110	454.	90.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
643	31,34,43,62,51,73,94,103,98,114	480.	104.
644	35,43,62,51,73,91,92,97,103,110	307.	72.
645	36,43,62,51,73,94,103,99,114	380.	85.
646	31,34,43,61,51,72,91,93,97,103,110	307.	57.
647	31,33,43,63,52,74,91,93,97,103,110	307.	67.
648	31,33,43,63,52,74,94,103,99,114	433.	84.
649	31,34,43,62,51,74,91,93,96,103,114	308.	65.
650	31,34,43,62,51,74,91,93,97,103,114	389.	78.
651	31,34,43,62,51,74,94,103,99,114	455.	91.
652	30,33,44,61,51,71,94,101,98,110	309.	63.
653	30,33,44,61,51,71,94,102,98,110	319.	68.
654	37,43,62,51,73,91,93,97,103,114	311.	66.
655	31,33,44,63,51,72,94,102,98,114	312.	68.
656	31,33,44,63,51,72,94,102,99,110	359.	77.
657	31,33,44,63,51,72,94,102,98,110	395.	77.
658	30,34,43,61,52,74,94,103,98,110	314.	67.
659	35,44,61,51,73,91,92,97,103,110	314.	66.
660	35,44,61,51,73,94,103,99,110	386.	82.
661	35,44,61,51,73,94,102,99,114	391.	86.
662	30,33,44,63,51,72,94,103,98,110	315.	68.
663	31,33,44,61,51,73,91,93,96,103,114	315.	65.
664	31,34,44,62,51,73,91,93,97,101,114	316.	71.
665	31,34,44,62,51,73,91,92,97,102,114	336.	73.
666	31,34,44,62,51,73,91,93,96,103,114	351.	70.
667	31,34,44,62,51,73,94,101,98,110	379.	82.
668	30,33,44,62,51,74,91,93,96,101,114	316.	71.
669	30,33,44,62,51,74,94,102,98,114	380.	84.
670	31,33,43,61,51,74,91,93,96,103,114	317.	69.
671	31,33,43,61,51,74,91,93,96,103,114	473.	92.
672	31,33,43,61,51,74,94,103,98,110	495.	97.
673	31,33,44,61,51,72,94,102,98,110	318.	69.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
674	31,33,43,62,52,73,91,93,96,103,110	318.	63.
675	30,34,44,61,51,74,91,93,97,103,110	319.	64.
676	30,34,44,61,51,74,91,93,97,103,114	356.	72.
677	37,44,63,51,74,91,93,97,102,114	319.	71.
678	37,44,63,51,74,94,101,99,114	415.	88.
679	37,44,63,51,74,94,103,99,110	452.	102.
680	36,44,63,51,71,94,103,98,110	321.	73.
681	35,44,63,51,74,91,93,96,101,110	321.	71.
682	35,44,63,51,74,91,93,97,102,110	326.	73.
683	35,44,63,51,74,91,93,96,101,110	398.	85.
684	35,44,63,51,74,94,101,99,114	405.	87.
685	35,44,63,41,74,94,101,98,114	408.	92.
686	35,44,63,51,74,94,102,98,114	518.	116.
687	35,43,63,51,74,91,93,97,103,110	323.	70.
688	35,43,63,51,74,91,93,97,103,114	326.	72.
689	35,43,63,51,74,91,93,97,103,110	330.	75.
690	35,43,63,51,74,94,103,98,110	417.	87.
691	35,43,63,51,74,94,103,99,110	463.	98.
692	35,43,63,51,74,94,103,99,114	466.	97.
693	30,33,43,61,52,73,94,103,98,110	323.	66.
694	30,34,44,63,52,73,94,102,98,114	323.	68.
695	35,43,62,51,74,94,103,98,114	324.	68.
696	35,43,62,51,74,91,93,96,103,114	335.	74.
697	35,43,62,51,74,94,103,99,110	367.	81.
698	30,33,44,63,51,74,91,93,96,103,114	326.	73.
699	30,33,44,63,51,74,91,93,97,102,110	346.	76.
700	30,33,44,63,51,74,94,102,98,110	470.	99.
701	30,34,43,61,51,73,94,103,98,110	326.	70.
702	30,34,43,61,51,73,91,92,97,103,110	364.	73.
703	31,33,44,63,52,73,91,92,96,102,114	327.	74.
704	31,33,44,63,52,73,91,93,97,103,110	328.	71.
705	31,33,44,63,52,73,91,92,96,103,110	347.	77.
706	31,33,44,63,52,73,91,92,97,101,114	371.	82.
707	31,33,44,63,52,73,94,103,98,114	371.	80.
708	31,33,44,63,52,73,94,101,99,114	420.	89.
709	37,43,63,51,74,91,93,96,103,110	328.	71.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total Cost (nearest $) $/T DP Fed	$/T DM Fed
710	37,43,63,51,74,94,103,98,110	378.	85.
711	37,43,63,51,74,94,103,99,114	430.	98.
712	37,43,63,51,74,94,103,98,114	579.	121!.
713	30,34,43,62,51,74,91,93,97,103,114	329.	64.
714	30,34,43,62,51,74,91,93,96,103,114	330.	68.
715	30,34,43,62,51,74,91,93,97,103,114	330.	67.
716	30,34,43,62,51,74,94,103,98,114	495.	98.
717	31,33,44,62,52,73,94,101,98,114	334.	65.
718	30,33,43,63,52,72,94,103,98,110	336.	72.
719	30,33,43,63,52,72,94,103,99,110	431.	78.
720	37,44,63,51,73,91,92,97,103,110	338.	73.
721	37,44,63,51,73,94,103,98,110	400.	90.
722	37,44,63,51,73,94,101,99,114	416.	91.
723	37,44,63,51,73,94,101,98,110	481.	99.
724	37,43,63,51,73,91,92,97,103,110	338.	72.
725	37,43,63,51,73,91,93,97,103,110	344.	78.
726	37,43,63,51,73,91,92,97,103,110	370.	75.
727	31,33,44,61,51,71,94,101,99,110	342.	71.
728	31,34,44,61,51,74,91,93,96,101,110	344.	76.
729	30,34,43,63,51,74,91,93,96,103,110	344.	79.
730	30,34,43,63,51,74,94,103,98,114	485.	100.
731	30,34,43,63,51,74,94,103,99,110	534.	108.
732	30,33,43,62,51,73,94,103,98,114	345.	73.
733	30,33,43,62,51,73,91,93,96,103,114	401.	77.
734	35,43,63,51,71,94,103,98,110	346.	73.
735	30,34,43,63,51,73,91,92,96,103,110	351.	76.
736	30,34,44,61,51,71,94,102,98,114	353.	73.
737	31,33,44,63,51,73,91,92,97,101,114	354.	75.
738	31,33,44,63,51,73,94,101,98,110	438.	94.
739	31,33,43,61,51,73,91,93,96,103,114	355.	78.
740	35,44,63,51,73,94,102,99,114	356.	82.
741	35,44,63,51,73,94,101,98,114	396.	87.
742	35,44,63,51,73,94,101,99,114	397.	86.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
743	30,34,44,61,51,73,94,102,98,114	356.	80.
744	30,34,44,61,51,73,94,101,99,114	438.	90.
745	30,33,43,62,52,73,94,103,99,114	357.	77.
746	30,34,43,63,52,74,94,103,98,110	358.	76.
747	30,34,43,63,52,74,94,103,99,110	369.	78.
748	30,34,43,63,52,74,94,103,98,114	397.	86.
749	30,34,43,63,52,74,94,103,98,110	399.	78.
750	30,34,43,63,52,74,94,103,98,114	401.	78.
751	30,34,43,61,51,74,94,103,99,114	359.	74.
752	30,34,43,61,51,74,94,103,98,110	455.	88.
753	31,33,43,62,51,74,94,103,98,110	360.	70.
754	30,33,43,61,51,74,91,93,97,103,114	361.	78.
755	30,34,44,62,51,73,91,93,97,102,110	362.	75.
756	31,33,43,63,52,72,94,103,98,114	366.	76.
757	31,33,43,63,52,72,94,103,99,110	384.	79.
758	30,33,44,63,51,73,91,92,97,102,110	368.	79.
759	30,33,44,63,51,73,94,103,98,114	488.	94.
760	30,33,43,63,51,72,94,103,98,114	369.	79.
761	30,33,43,63,51,72,91,93,96,103,114	381.	72.
762	36,44,62,51,73,94,103,98,114	370.	85.
763	36,44,62,51,73,94,103,99,114	394.	82.
764	31,34,43,63,51,73,91,93,97,103,110	371.	84.
765	36,43,63,51,72,94,103,99,110	372.	78.
766	35,43,63,51,73,94,103,98,114	375.	83.
767	35,43,63,51,73,91,92,97,103,114	385.	75.
768	35,43,63,51,73,94,103,98,114	388.	89.
769	35,43,63,51,73,91,92,96,103,114	391.	86.
770	35,43,63,51,73,94,103,99,110	392.	79.
771	35,43,63,51,73,94,103,99,114	472.	101.
772	31,34,44,63,51,74,91,93,97,103,114	378.	81.
773	31,34,43,63,51,74,91,93,97,103,114	379.	78.

TABLE K3. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
774	30,33,44,61,51,73,94,103,99,114	380.	86.
775	31,33,44,63,52,72,94,101,98,110	383.	74.
776	30,33,43,63,51,71,94,103,98,110	386.	85.
777	30,33,43,63,51,71,94,103,99,110	406.	87.
778	30,33,43,63,51,71,94,103,98,110	410.	80.
779	30,34,44,63,51,74,91,93,96,103,114	387.	83.
780	30,34,44,63,51,74,94,103,99,114	473.	97.
781	31,33,43,63,51,74,91,93,97,103,114	387.	77.
782	31,33,43,63,51,73,91,92,97,103,110	390.	84.
783	31,33,43,63,51,73,91,93,97,103,110	409.	80.
784	31,33,43,63,51,73,91,92,96,103,110	512.	96.
785	30,34,43,62,51,73,94,103,98,114	395.	79.
786	31,34,44,62,51,74,94,103,99,110	399.	83.
787	31,34,44,62,51,74,94,101,98,110	474.	104.
788	30,34,44,63,52,74,94,101,98,110	402.	87.
789	30,34,44,63,52,74,94,102,99,110	424.	91.
790	30,33,43,63,51,74,91,93,96,103,110	405.	86.
791	30,33,43,63,51,74,94,103,98,110	436.	90.
792	30,33,43,63,51,74,91,93,96,103,110	466.	90.
793	30,33,43,63,51,73,91,92,97,103,110	406.	85.
794	30,33,43,63,51,73,94,103,99,114	460.	96.
795	30,34,43,63,52,73,94,103,99,110	428.	87.
796	30,33,44,62,51,73,94,101,99,110	446.	93.
797	30,33,44,62,51,73,94,103,98,114	538.	100.
798	31,34,43,63,52,73,94,103,99,114	509.	102.
799	31,34,43,61,51,74,94,103,99,114	542.	116.
800	31,33,44,62,51,73,94,102,99,110	616.	131.

TABLE K4. FORAGE HANDLING SYSTEMS SIMULATED FOR 300 ACRES - PRE-CUT HARVESTING

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
1	37,44,61,52,72,91,93,96,102,110	134.	29.
2	37,44,61,52,72,94,101,99,110	232.	49.
3	36,44,61,52,71,91,92,97,103,114	135.	29.
4	36,44,61,52,71,91,93,97,103,110	155.	33.
5	36,44,61,52,71,91,92,96,103,110	158.	34.
6	36,44,61,52,71,91,93,97,103,114	180.	38.
7	36,44,62,52,71,91,93,96,101,110	136.	28.
8	36,44,62,52,71,91,92,96,103,110	157.	33.
9	36,44,62,52,71,94,101,98,110	265.	55.
10	37,43,62,51,71,91,93,97,103,110	137.	31.
11	37,43,62,51,71,91,93,96,103,110	219.	45.
12	37,43,62,51,71,94,103,98,110	273.	60.
13	36,44,62,52,72,91,93,97,103,114	138.	31.
14	36,44,62,52,72,91,93,97,103,114	142.	33.
15	36,44,62,52,72,91,93,96,102,110	161.	35.
16	36,44,62,52,72,91,93,96,101,110	188.	41.
17	36,44,62,52,72,94,101,98,114	207.	45.
18	36,44,61,51,72,91,93,96,103,110	140.	31.
19	36,44,61,51,72,91,93,97,102,114	157.	33.
20	36,44,61,51,72,91,93,97,101,114	188.	40.
21	37,43,62,52,71,91,93,97,103,114	140.	30.
22	37,43,62,52,71,91,92,96,103,114	171.	35.
23	37,43,62,52,71,91,92,97,103,114	180.	35.
24	37,43,62,52,71,94,103,99,114	253.	49.
25	36,43,62,52,72,91,93,97,103,114	144.	32.
26	36,43,62,52,72,91,93,96,103,110	145.	31.
27	36,43,62,52,72,91,93,96,103,114	150.	32.
28	36,43,62,52,72,91,93,97,103,110	169.	35.
29	36,43,62,52,72,91,93,96,103,110	172.	36.
30	36,43,62,52,72,94,103,98,114	180.	38.
31	36,44,62,52,72,91,93,96,103,110	145.	33.
32	36,44,63,52,72,91,93,97,102,114	149.	33.
33	36,44,63,52,72,91,93,96,101,110	161.	35.
34	36,44,63,52,72,91,93,97,101,110	194.	42.
35	36,44,63,52,72,94,101,98,114	231.	50.
36	36,44,63,52,72,94,102,98,110	241.	53.
37	36,44,63,52,72,91,93,97,102,110	248.	52.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
38	36,43,62,51,71,91,92,96,103,110	146.	33.
39	36,43,62,51,71,94,103,98,110	222.	49.
40	36,43,62,51,71,91,93,96,103,110	247.	48.
41	36,43,62,51,71,94,103,98,110	283.	62.
42	36,43,62,51,71,94,103,98,110	295.	58.
43	37,44,61,52,71,91,93,96,102,110	146.	30.
44	37,44,61,52,71,91,92,96,101,110	166.	36.
45	37,44,61,52,71,94,102,99,114	174.	38.
46	37,44,61,52,71,91,92,96,102,114	195.	39.
47	37,44,61,52,71,94,101,98,114	202.	42.
48	37,44,63,52,72,91,93,96,101,110	147.	33.
49	37,44,63,52,72,94,103,98,114	200.	43.
50	37,44,63,52,72,91,93,97,102,114	211.	47.
51	37,44,63,52,72,94,102,99,110	262.	57.
52	36,44,61,52,73,91,93,96,102,114	147.	33.
53	36,44,61,52,73,94,102,99,114	171.	40.
54	36,44,61,52,73,91,92,96,102,114	183.	41.
55	36,44,61,52,73,94,102,98,114	191.	41.
56	36,44,62,52,74,91,93,96,102,110	153.	35.
57	36,44,62,52,74,91,93,96,101,114	165.	37.
58	36,44,62,52,74,94,103,99,114	214.	48.
59	36,44,62,52,74,94,102,99,110	242.	55.
60	36,44,61,51,71,91,92,96,103,114	153.	34.
61	36,44,61,51,71,91,93,97,101,114	185.	41.
62	36,44,61,51,71,91,92,97,103,114	205.	42.
63	36,44,61,51,71,91,93,97,102,114	205.	43.
64	36,44,61,51,71,91,93,96,101,114	209.	46.
65	36,44,61,51,71,94,103,98,110	253.	58.
66	36,44,61,51,71,94,101,99,114	253.	54.
67	35,43,61,52,72,91,93,96,103,110	158.	34.
68	35,43,61,52,72,91,93,96,103,110	175.	36.
69	35,43,61,52,72,94,103,99,114	210.	43.
70	35,43,61,52,72,94,103,99,110	236.	49.
71	36,44,62,51,71,91,92,97,102,114	161.	36.
72	36,44,62,51,71,91,93,97,102,110	169.	36.
73	36,44,62,51,71,91,92,96,101,114	182.	40.
74	36,44,62,51,71,94,102,98,114	204.	45.
75	36,44,62,51,71,91,92,97,101,114	230.	48.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
76	36,43,62,52,73,91,93,96,103,110	161.	36.
77	36,43,62,52,73,91,93,96,102,110	177.	40.
78	36,43,62,52,73,91,92,96,103,110	180.	40.
79	36,43,62,52,73,91,92,96,103,114	202.	43.
80	37,44,62,52,73,91,92,97,101,110	163.	36.
81	37,44,62,52,73,91,92,97,102,110	210.	44.
82	37,44,62,52,73,94,101,98,114	222.	47.
83	37,44,62,52,73,94,103,99,110	237.	54.
84	37,43,61,52,72,91,93,97,103,114	164.	36.
85	37,43,61,52,72,91,93,96,103,114	208.	44.
86	37,43,61,52,72,94,103,98,114	241.	47.
87	37,44,62,51,71,91,92,97,101,110	166.	37.
88	37,44,62,51,71,91,93,97,103,114	230.	45.
89	37,43,61,52,71,94,103,98,114	168.	37.
90	37,43,61,52,71,91,92,96,103,114	184.	37.
91	37,43,61,52,71,94,103,99,114	215.	43.
92	37,43,61,52,71,94,103,98,114	306.	53.
93	37,44,61,51,72,91,93,97,101,110	168.	37.
94	37,44,61,51,72,91,93,97,101,110	227.	50.
95	37,44,61,51,72,94,103,98,110	275.	61.
96	37,44,61,51,72,94,101,98,110	288.	61.
97	37,44,61,51,72,91,93,97,103,114	296.	60.
98	37,44,63,52,71,91,92,96,102,110	168.	35.
99	37,44,63,52,71,91,93,97,102,114	235.	51.
100	37,44,63,52,71,94,102,99,114	237.	51.
101	36,43,62,51,72,91,93,97,103,110	169.	37.
102	36,43,62,51,72,94,103,99,110	260.	56.
103	36,43,62,51,72,94,103,98,110	294.	61.
104	37,44,63,52,73,91,93,96,102,114	170.	38.
105	37,44,63,52,73,91,93,97,102,114	244.	54.
106	37,44,63,52,73,94,102,99,114	269.	58.
107	37,44,63,52,73,94,102,98,110	270.	57.
108	37,43,62,52,74,91,93,96,103,114	173.	38.
109	37,43,62,52,74,94,103,98,110	197.	43.
110	37,43,62,52,74,94,103,98,114	229.	51.
111	37,43,62,52,74,94,103,98,110	253.	54.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
112	36,44,62,51,72,91,93,97,102,110	173.	37.
113	36,44,62,51,72,94,101,98,114	195.	44.
114	36,44,62,51,72,94,103,99,114	254.	52.
115	37,43,61,51,72,91,93,96,103,110	174.	37.
116	35,44,61,52,72,91,93,96,103,114	174.	35.
117	35,44,61,52,72,91,93,96,102,114	176.	34.
118	35,44,61,52,72,91,93,96,101,110	180.	36.
119	35,44,61,52,72,91,93,97,102,110	244.	50.
120.	36,43,61,52,71,91,92,96,103,110	174.	38.
121	36,43,61,52,71,94,103,98,114	236.	49.
122	36,43,61,52,71,94,103,99,110	248.	47.
123	36,43,61,52,71,94,103,98,110	257.	57.
124	36,43,61,52,72,91,93,97,103,110	175.	36.
125	36,43,61,52,72,94,103,98,114	198.	41.
126	36,43,61,52,72,94,103,99,110	218.	46.
127	36,43,61,52,72,94,103,99,114	253.	54.
128	36,43,62,52,71,94,103,99,114	176.	38.
129	36,43,62,52,71,91,92,97,103,110	180.	40.
130	36,43,62,52,71,91,93,96,103,110	182.	37.
131	36,43,62,52,71,94,103,98,110	226.	47.
132	30,33,43,61,52,71,91,92,96,103,114	177.	36.
133	30,33,43,61,52,71,91,93,96,103,114	189.	40.
134	30,33,43,61,52,71,91,93,97,103,114	210.	42.
135	30,33,43,61,52,71,94,103,99,114	225.	47.
136	30,33,43,61,52,71,94,103,99,114	290.	53.
137	30,33,43,61,52,71,94,103,99,110	374.	66.
138	36,43,63,52,71,91,92,97,103,110	177.	39.
139	36,43,63,52,71,94,103,99,110	219.	47.
140	36,43,63,52,71,94,103,98,110	238.	52.
141	36,43,63,52,71,94,103,98,110	284.	62.
142	36,43,61,52,73,91,93,97,103,114	180.	40.
143	36,43,61,52,73,94,103,99,110	215.	47.
144	36,43,61,52,73,94,103,99,110	228.	49.
145	36,43,61,52,73,91,92,96,103,114	235.	50.
146	30,34,44,61,52,74,91,93,96,103,110	182.	38.
147	30,34,44,61,52,74,94,103,98,114	225.	47.
148	30,34,44,61,52,74,91,93,96,101,110	242.	50.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
149	37,43,61,52,73,91,92,97,103,114	183.	40.
150	37,43,61,52,73,91,93,97,103,114	199.	42.
151	37,43,61,52,73,91,93,97,103,114	265.	58.
152	37,43,61,52,73,94,103,99,114	265.	59.
153	37,43,61,52,73,94,103,98,114	275.	55.
154	37,43,61,52,73,94,103,98,114	276.	56.
155	37,43,61,52,73,94,103,99,110	290.	57.
156	35,44,61,51,71,94,103,99,114	183.	39.
157	35,44,61,51,71,91,92,96,102,110	268.	52.
158	35,44,61,51,71,94,103,98,110	273.	57.
159	37,43,63,51,72,91,93,97,103,114	184.	41.
160	37,43,63,51,72,91,93,97,103,110	206.	47.
161	37,43,63,51,72,91,93,96,103,114	284.	54.
162	36,44,63,52,71,91,93,96,102,114	185.	39.
163	36,44,63,52,71,91,92,97,101,114	217.	46.
164	36,44,63,52,71,94,103,99,114	232.	47.
165	36,44,63,52,71,94,102,99,110	267.	58.
166	36,43,61,51,71,91,93,97,103,110	185.	37.
167	36,43,61,51,71,91,92,97,103,110	194.	40.
168	36,43,61,51,71,94,103,98,114	234.	51.
169	36,43,61,51,71,94,103,98,110	303.	63.
170	35,43,63,52,71,91,92,96,103,114	185.	41.
171	35,43,63,52,71,94,103,99,110	293.	61.
172	35,43,63,52,71,94,103,99,114	320.	62.
173	37,43,62,52,72,94,103,98,114	186.	39.
174	37,43,62,52,72,94,103,98,114	207.	44.
175	37,43,62,52,72,94,103,98,114	214.	48.
176	37,43,62,52,72,91,93,96,103,114	227.	44.
177	36,44,61,51,73,91,92,97,103,110	187.	42.
178	36,44,61,51,73,94,101,99,114	307.	64.
179	37,43,62,51,72,91,93,96,102,114	188.	42.
180	37,43,62,51,72,91,93,97,103,114	190.	39.
181	37,43,62,51,72,94,103,98,114	217.	49.
182	37,43,62,51,72,94,103,99,114	273.	57.
183	37,43,62,51,72,94,103,99,110	335.	66.
184	36,44,61,52,74,91,93,96,101,110	188.	41.
185	36,44,61,52,74,94,103,98,114	250.	56.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
186	30,33,44,61,52,71,91,93,97,102,114	189.	40.
187	30,33,44,61,52,71,94,102,98,114	277.	54.
188	37,44,62,52,74,91,93,97,102,114	189.	39.
189	37,44,62,52,74,94,102,99,114	195.	44.
190	37,44,62,52,74,94,103,99,114	204.	46.
191	37,44,62,52,74,94,103,99,114	251.	48.
192	35,44,62,52,72,91,93,97,103,110	189.	36.
193	35,44,62,52,72,91,93,97,101,114	199.	41.
194	35,44,62,52,72,91,93,97,101,114	244.	51.
195	37,44,62,52,71,91,93,97,102,110	190.	39.
196	37,44,62,52,71,94,102,98,110	200.	44.
197	37,44,62,52,71,94,101,98,110	226.	46.
198	37,44,62,52,71,94,101,98,110	251.	50.
199	37,44,62,52,71,91,92,96,103,110	267.	49.
200	35,44,62,52,74,91,93,97,103,110	190.	40.
201	35,44,62,52,74,94,103,99,114	224.	47.
202	36,43,61,52,74,91,93,97,103,114	190.	44.
203	36,43,61,52,74,94,103,98,110	227.	48.
204	36,44,62,52,73,91,92,97,102,110	191.	42.
205	30,33,44,62,52,72,91,93,96,102,110	191.	40.
206	30,33,44,62,52,72,94,103,99,114	216.	45.
207	37,43,61,52,74,91,93,96,103,110	193.	44.
208	37,43,61,52,74,91,93,97,103,110	277.	52.
209	35,43,62,52,73,91,92,96,103,110	193.	42.
210	35,43,62,52,73,91,92,97,103,114	220.	47.
211	35,43,62,52,73,91,93,97,103,114	231.	46.
212	35,43,62,52,73,94,103,98,110	238.	52.
213	35,43,62,52,73,91,93,97,103,110	256.	48.
214	35,44,61,51,72,91,93,97,103,110	193.	39.
215	35,44,61,51,72,91,93,97,103,114	200.	41.
216	35,44,61,51,72,91,93,97,101,114	209.	45.
217	35,44,61,51,72,91,93,96,101,114	243.	48.
218	37,43,62,52,73,94,103,99,114	196.	42.
219	37,43,62,52,73,91,93,96,103,114	214.	48.
220	37,43,62,52,73,91,93,96,103,114	268.	56.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
221	35,43,61,52,74,91,93,97,103,110	196.	43.
222	35,43,61,52,74,94,103,99,110	198.	42.
223	35,43,61,52,74,91,93,97,103,110	201.	44.
224	35,43,61,52,74,91,93,97,103,110	257.	49.
225	35,43,61,52,74,94,103,98,110	263.	54.
226	35,43,61,52,74,91,93,97,103,110	347.	63.
227	35,44,62,51,72,91,93,96,102,114	198.	41.
228	35,44,62,51,72,91,93,97,102,110	217.	41.
229	35,44,62,51,72,94,102,98,114	289.	55.
230	36,44,63,52,73,94,102,99,114	198.	46.
231	36,44,63,52,73,91,93,97,102,110	206.	46.
232	36,44,63,52,73,94,103,98,114	215.	48.
233	36,44,63,52,73,91,92,97,103,114	248.	53.
234	36,44,63,52,73,91,93,97,101,114	281.	61.
235	36,44,63,52,73,94,103,98,110	314.	69.
236	35,44,61,52,74,91,93,96,101,114	198.	43.
237	35,44,61,52,74,94,103,98,114	206.	43.
238	35,43,61,52,71,91,92,97,103,114	202.	41.
239	35,43,61,52,71,91,93,97,103,114	237.	49.
240	35,43,61,52,71,91,93,96,103,114	276.	54.
241	36,44,63,52,74,91,93,97,102,110	203.	45.
242	36,44,63,52,74,91,93,97,102,114	232.	51.
243	36,44,63,52,74,94,101,98,110	327.	69.
244	30,33,44,61,52,74,91,93,97,103,114	203.	43.
245	30,33,44,61,52,74,91,93,97,103,114	224.	47.
246	30,33,44,61,52,74,94,103,98,114	226.	48.
247	30,33,44,61,52,74,94,103,99,114	242.	49.
248	30,33,44,61,52,74,94,102,99,114	270.	54.
249	30,33,44,61,52,74,94,103,99,110	334.	66.
250	36,43,63,52,74,91,93,96,103,110	203.	47.
251	36,43,63,52,74,94,103,99,110	259.	60.
252	36,43,63,52,74,94,103,98,114	303.	65.
253	36,43,63,52,74,94,103,98,114	330.	64.
254	30,34,44,63,52,71,91,92,96,103,114	203.	43.
255	30,34,43,61,52,71,91,92,96,103,114	204.	41.
256	37,43,63,52,72,91,93,96,103,110	204.	46.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
257	37,43,63,52,72,94,103,99,114	204.	47.
258	37,43,63,52,72,94,103,99,110	233.	51.
259	37,43,63,52,72,94,103,98,110	242.	54.
260	37,43,63,52,72,94,103,98,114	289.	64.
261	35,44,62,52,73,91,92,97,103,114	204.	45.
262	35,44,62,52,73,91,92,97,102,114	212.	44.
263	35,44,62,52,73,91,93,96,102,110	214.	43.
264	35,44,62,52,73,94,103,98,110	312.	68.
265	30,33,44,61,52,73,91,92,96,102,110	204.	43.
266	30,33,44,61,52,73,94,101,98,114	292.	57.
267	35,44,63,52,71,91,92,97,101,114	204.	44.
268	35,44,63,52,71,91,92,96,101,110	239.	47.
269	35,44,63,52,71,94,102,99,110	292.	61.
270	35,44,62,52,71,91,93,96,102,110	205.	42.
271	31,33,43,61,52,72,91,93,97,103,110	205.	42.
272	31,33,43,61,52,72,94,103,99,114	288.	57.
273	31,33,43,61,52,72,94,103,98,114	337.	64.
274	35,44,61,52,71,91,92,96,101,114	206.	41.
275	35,44,61,52,71,91,93,97,103,114	233.	47.
276	35,44,61,52,71,91,93,97,101,114	241.	46.
277	35,43,62,52,72,94,103,98,114	207.	43.
278	35,43,62,52,72,94,103,99,110	277.	53.
279	31,34,43,62,52,72,91,93,97,103,110	207.	43.
280	31,34,43,62,52,72,91,93,97,103,114	215.	43.
281	31,34,43,62,52,72,94,103,99,114	240.	49.
282	31,34,43,62,52,72,94,103,99,114	288.	55.
283	36,43,62, 52,74,91,93,97,103,110	210.	42.
284	36,43,62,52,74,94,103,98,114	216.	45.
285	36,43,62,52,74,94,103,99,110	226.	48.
286	36,43,62,52,74,94,103,99,114	230.	48.
287	37,43,63,52,71,91,92,96,103,110	211.	45.
288	37,43,63,52,71,94,103,99,110	268.	60.
289	37,43,63,52,71,94,103,98,114	270.	56.
290	37,43,63,52,71,94,103,98,110	280.	60.
291	37,43,63,52,71,94,103,98,110	375.	70.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
292	37,44,63,51,72,91,93,96,102,110	211.	43.
293	37,44,63,51,72,94,102,99,110	380.	78.
294	30,34,44,62,52,74,91,93,97,103,114.	212.	42.
295	30,34,44,62,52,74,94,102,99,114	251.	54.
296	30,34,44,62,52,74,94,103,98,114	389.	76.
297	35,43,61,51,72,91,93,97,103,110	213.	42.
298	35,43,61,51,72,91,93,96,103,114	233.	46.
299	35,43,61,51,72,94,103,98,110	283.	55.
300	31,33,44,61,52,74,91,93,102,114	214.	44.
301	31,33,44,61,52,74,91,93,96,101,110	256.	47.
302	31,33,44,61,52,74,94,102,98,114	256.	51.
303	30,33,43,61,52,72,91,93,97,103,110	214.	43.
304	37,43,61,51,74,91,93,96,103,114	215.	48.
305	37,43,61,51,74,91,93,97,103,114	215.	49.
306	37,43,61,51,74,91,93,97,103,110	236.	51.
307	37,43,61,51,74,91,93,96,103,110	248.	51.
308	37,43,61,51,74,91,93,96,103,110	282.	55.
309	37,43,61,51,74,94,103,98,110	290.	64.
310	37,43,61,51,74,91,93,97,103,114	293.	57.
311	37,43,61,51,74,91,93,97,103,110	321.	68.
312	37,43,61,51,74,91,93,96,103,114	321.	59.
313	37,43,61,51,74,94,103,99,110	333.	73.
314	37,43,61,51,74,94,103,98,110	436.	86.
315	37,44,61,51,74,91,93,97,101,114	216.	49.
316	37,44,61,51,74,94,102,99,114	301.	62.
317	37,44,61,51,74,94,101,98,110	317.	70.
318	36,44,61,51,74,91,93,97,102,110	216.	46.
319	36,44,61,51,74,91,93,97,101,110	223.	49.
320	36,44,61,51,74,94,101,99,114	299.	67.
321	31,34,44,62,52,71,91,93,96,102,110	216.	41.
322	36,43,61,51,72,91,93,96,103,114	217.	42.
323	36,43,61,51,72,94,103,98,114	229.	48.
324	36,43,61,51,72,94,103,99,110	231.	49.
325	36,43,61,51,72,94,103,98,110	267.	57.
326	36,43,61,51,72,94,103,99,110	285.	62.
327	36,43,61,51,72,94,103,98,110	315.	65.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
328	35,43,62,52,71,91,93,96,103,114	218.	46.
329	35,43,62,52,71,91,93,96,103,114	228.	42.
330	31,33,44,61,52,72,94,101,98,114	218.	45.
331	31,33,44,61,52,72,94,103,99,110	266.	53.
332	30,34,44,62,51,71,91,93,97,102,110	219.	46.
333	30,34,44,61,52,72,91,93,96,103,114	219.	43.
334	37,43,61,51,71,91,93,96,103,114	220.	45.
335	36,44,61,52,72,94,101,98,110	220.	47.
336	31,34,43,62,51,72,91,93,97,103,110	221.	46.
337	31,34,43,62,51,73,94,103,99,110	377.	77.
338	35,44,61,52,73,94,101,98,114	222.	49.
339	35,44,61,52,73,94,102,98,114	224.	47.
340	35,44,61,52,73,94,101,98,110	273.	55.
341	36,43,61,51,74,91,93,97,103,110	222.	47.
342	36,43,61,51,74,91,93,96,103,110	223.	50.
343	36,43,61,51,74,94,103,98,110	300.	62.
344	36,43,61,51,74,94,103,98,110	346.	72.
345	36,43,61,51,74,94,103,98,114	347.	72.
346	35,44,61,51,74,91,93,97,102,114	223.	49.
347	35,44,61,51,74,94,102,98,110	363.	75.
348	37,43,63,51,71,91,93,97,103,110	224.	47.
349	37,43,63,51,71,91,93,97,103,114	225.	49.
350	37,43,63,51,71,91,92,96,103,114	240.	51.
351	37,43,63,51,71,94,103,98,114	255.	53.
352	31,33,44,61,52,73,91,93,96,102,110	225.	45.
353	37,44,61,52,73,91,93,97,101,110	225.	48.
354	37,44,61,52,73,94,101,99,110	306.	64.
355	31,33,44,62,51,71,91,93,97,101,110	336.	47.
356	31,33,44,62,51,71,94,103,98,110	346.	66.
357	37,44,63,51,71,91,92,96,101,114	227.	49.
358	37,44,63,51,71,91,92,97,101,114	282.	59.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
359	31,33,44,61,52,71,91,93,96,102,110	228.	44.
360	31,33,44,61,52,71,94,101,98,110	321.	65.
361	35,43,62,52,74,91,93,97,103,110	228.	47.
362	35,43,62,52,74,91,93,96,103,110	235.	46.
363	35,43,62,52,74,94,103,99,114	245.	50.
364	30,33,44,61,51,72,91,93,97,102,114	228.	46.
365	30,33,44,61,51,72,94,103,98,114	296.	58.
366	31,34,44,62,51,72,91,93,96,103,110	228.	46.
367	31,34,44,62,51,72,91,93,96,102,114	233.	50.
368	31,34,44,62,51,72,91,93,96,102,110	235.	47.
369	31,34,43,61,52,71,91,92,96,103,114	228.	46.
370	31,34,43,61,52,71,94,103,98,114	234.	48.
371	31,34,43,61,52,71,94,103,98,114	319.	64.
372	30,33,44,63,52,71,91,93,96,101,110	229.	48.
373	30,33,44,63,52,71,91,93,97,101,110	299.	59.
374	30,33,44,63,52,71,91,92,96,103,110	303.	57.
375	30,33,44,63,52,71,94,101,98,110	329.	68.
376	30,33,44,63,52,71,94,101,98,110	363.	73.
377	30,33,44,63,52,71,94,103,98,110	372.	78.
378	37,43,63,52,73,91,93,97,103,110	230.	50.
379	37,43,63,52,73,91,92,97,103,114	276.	58.
380	35,44,63,51,71,91,92,97,102,114	230.	49.
381	35,44,63,51,71,94,102,99,114	290.	59.
382	31,34,44,63,52,71,91,92,96,102,110	231.	46.
383	30,33,44,63,52,73,91,93,96,103,114	231.	48.
384	37,44,62,51,74,91,93,97,103,114	231.	53.
385	37,44,62,51,74,91,93,97,103,114	236.	50.
386	37,44,62,51,74,91,93,96,102,114	245.	55.
387	37,44,62,51,72,91,93,96,102,110	232.	47.
388	37,44,62,51,72,94,101,98,110	256.	56.
389	37,44,62,51,72,94,102,99,114	278.	59.
390	31,33,44,63,52,71,91,92,97,103,110	233.	50.
391	31,33,44,63,52,71,91,93,97,101,110	256.	52.
392	31,33,44,63,52,71,94,103,99,110	308.	64.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
393	31,33,43,61,51,72,91,93,97,103,114	234.	47.
394	31,33,43,61,51,72,94,103,99,114	298.	61.
395	37,44,61,52,74,91,93,96,101,114	234.	47.
396	37,44,61,52,74,94,101,98,110	235.	52.
397	37,44,61,52,74,94,103,99,110	256.	58.
398	31,34,44,61,51,71,91,92,97,101,110	235.	47.
399	35,43,63,52,72,94,103,98,110	235.	51.
400	35,43,63,52,72,91,93,97,103,114	251.	48.
401	35,43,63,52,72,91,93,97,103,114	284.	54.
402	35,43,62,51,71,91,93,96,103,110	236.	47.
403	36,43,63,52,73,94,103,98,114	236.	53.
404	36,43,63,52,73,94,103,99,114	251.	52.
405	36,43,63,52,73,94,103,98,114	267.	59.
406	36,43,63,52,73,94,103,98,114	301.	66.
407	35,44,63,51,72,94,101,99,114	237.	51.
408	35,44,63,51,72,91,93,97,101,110	254.	54.
409	35,44,63,51,72,94,103,99,114	291.	60.
410	35,44,63,51,72,94,102,99,114	332.	67.
411	30,34,44,62,52,71,94,101,99,114	238.	49.
412	30,34,43,62,52,74,91,93,96,103,114	238.	48.
413	30,34,43,62,52,74,94,103,98,110	295.	58.
414	30,34,43,62,52,74,91,93,96,103,114	305.	58.
415	30,34,43,62,52,74,91,93,97,103,110	352.	62.
416	37,43,62,51,74,91,93,97,103,114	238.	49.
417	35,44,63,52,74,91,93,96,102,114	239.	51.
418	35,44,63,52,74,94,101,99,114	252.	56.
419	30,33,44,61,52,72,91,93,97,103,110	240.	45.
420	37,44,61,51,73,94,101,98,114	240.	55.
421	37,44,61,51,73,91,92,97,101,114	248.	53.
422	37,44,61,51,73,91,92,96,102,114	285.	58.
423	37,44,61,51,73,94,103,98,114	303.	64.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $)	
		$/T DP Fed	S/T DM Fed
424	36,44,63,51,73,91,93,97,102,110	240.	53.
425	36,44,63,51,73,91,93,97,102,110	287.	56.
426	36,44,63,51,73,94,102,99,114	366.	82.
427	35,43,61,51,73,91,93,97,103,114	240.	52.
428	35,43,61,51,73,91,92,96,103,110	283.	61.
429	35,43,61,51,73,94,103,98,110	304.	59.
430	35,43,61,51,73,94,103,99,114	332.	72.
431	35,43,61,51,73,94,103,98,114	440.	91.
432	30,34,43,61,52,73,94,103,98,114	241.	48.
433	30,33,43,62,51,72,91,93,97,103,114	241.	45.
434	30,33,43,62,51,72,91,93,97,103,110	258.	51.
435	36,43,62,51,74,94,103,99,114	242.	53.
436	36,43,62,51,74,94,103,99,114	287.	64.
437	36,43,62,51,74,94,103,99,110	324.	73.
438	31,34,44,61,52,73,94,102,98,114	242.	53.
439	35,44,63,52,73,91,92,96,103,114	242.	51.
440	35,44,63,52,73,91,92,97,101,110	259.	55.
441	35,44,63,52,73,94,102,98,114	276.	55.
442	35,44,63,52,73,94,101,98,114	278.	58.
443	35,44,63,52,73,94,103,98,114	284.	60.
444	30,33,44,62,51,72,91,93,96,103,114	242.	49.
445	30,33,44,62,51,72,91,93,97,101,114	263.	53.
446	30,33,44,62,51,72,94,102,98,110	353.	69.
447	30,33,43,62,52,71,91,93,97,103,114	243.	50.
448	30,33,43,62,52,71,94,103,98,114	254.	50.
449	30,33,43,62,52,71,94,103,99,114	257.	53.
450	36,43,63,52,72,94,103,98,110	243.	51.
451	36,43,63,52,72,91,93,96,103,110	252.	53.
452	36,43,63,52,72,94,103,99,114	269.	55.
453	30,34,44,62,52,73,91,92,97,102,114	244.	50.
454	35,44,63,52,72,94,103,98,114	244.	50.
455	35,44,63,52,72,94,103,98,110	284.	62.
456	30,34,43,62,52,71,94,103,99,114	245.	49.
457	30,34,43,62,52,71,91,93,97,103,114	246.	46.
458	30,34,43,62,52,71,91,93,96,103,110	256.	51.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
459	30,34,43,62,52,71,91,93,97,103,114	278.	56.
460	36,44,63,51,74,91,93,97,103,110	246.	54.
461	37,43,63,52,74,94,103,99,114	246.	53.
462	37,43,63,52,74,94,103,99,110	272.	63.
463	37,43,63,52,74,94,103,98,110	386.	76.
464	30,34,43,63,52,72,91,93,96,103,110	246.	52.
465	30,34,43,63,52,72,94,103,99,110	276.	58.
466	30,34,43,63,52,72,94,103,98,114	325.	66.
467	35,43,63,52,73,91,93,96,103,114	247.	54.
468	35,43,63,52,73,94,103,99,114	279.	58.
469	35,44,62,51,74,91,93,97,102,114	247.	51.
470	35,44,62,51,74,94,101,98,110	346.	74.
471	35,43,62,51,73,91,93,97,103,114	248.	55.
472	35,43,62,51,73,91,93,97,103,114	275.	55.
473	35,43,62,51,73,94,103,98,110	416.	86.
474	30,33,44,61,51,74,91,93,97,103,114	249.	53.
475	30,33,44,61,51,74,94,103,99,114	315.	64.
476	30,33,44,61,51,74,91,93,97,101,110	399.	75.
477	36,43,61,51,73,91,92,96,103,114	250.	50.
478	36,43,61,51,73,91,93,97,103,110	261.	55.
479	36,43,61,51,73,91,92,96,103,110	293.	59.
480	36,43,61,51,73,94,103,99,114	367.	77.
481	35,43,63,52,74,91,93,97,103,114	251.	53.
482	35,43,63,52,74,91,93,96,103,110	296.	60.
483	35,43,63,52,74,91,93,96,103,110	302.	62.
484	35,43,63,52,74,91,93,97,103,110	312.	60.
485	35,43,63,52,74,94,103,99,110	325.	63.
486	35,43,63,52,74,94,103,98,110	374.	70.
487	36,43,63,51,71,91,96,103,114	251.	52.
488	36,43,63,51,71,94,103,98,110	310.	66.
489	31,33,43,61,52,71,91,93,96,103,110	251.	55.
490	31,33,43,61,52,71,91,92,96,103,114	258.	49.
491	31,33,43,61,52,71,94,103,114	263.	54.
492	31,34,44,63,52,72,91,93,97,101,114	253.	50.
493	31,34,44,63,52,72,94,103,99,110	359.	69.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
494	31,33,44,63,52,74,91,93,96,103,114	253.	51.
495	31,33,43,62,52,74,94,103,99,114	254.	54.
496	31,33,43,62,52,74,91,93,97,103,114	300.	63.
497	31,34,43,61,52,74,91,93,96,103,110	255.	51.
498	30,34,44,61,52,71,94,101,98,110	256.	53.
499	30,34,44,61,52,71,94,103,98,110	269.	54.
500	37,44,62,51,73,91,93,97,102,110	257.	53.
501	37,44,62,51,73,91,93,96,102,114	290.	56.
502	31,34,43,62,51,71,91,93,97,103,110	258.	50.
503	31,34,43,62,51,71,94,103,99,114	289.	55.
504	31,34,43,62,51,71,94,103,98,110	333.	63.
505	31,33,44,63,51,71,91,92,97,101,114	259.	55.
506	31,33,44,63,51,71,94,102,99,110	376.	77.
507	31,33,44,63,51,71,94,102,98,110	382.	78.
508	35,44,62,51,71,94,102,99,110	259.	56.
509	35,44,62,51,71,91,93,96,101,110	266.	57.
510	35,44,62,51,71,94,101,99,114	281.	57.
511	35,44,62,51,71,94,102,99,110	307.	65.
512	36,43,63,51,73,91,92,97,103,114	260.	57.
513	36,43,63,51,73,94,103,99,110	271.	62.
514	36,43,63,51,73,91,92,97,103,114	276.	61.
515	36,43,63,51,73,91,92,96,103,110	276.	61.
516	36,43,63,51,73,91,93,96,103,110	302.	67.
517	36,43,63,51,73,94,103,98,110	361.	79.
518	31,34,44,61,51,72,91,93,96,102,110	260.	52.
519	30,33,44,63,52,74,91,93,97,101,110	260.	54.
520	30,33,43,62,52,72,94,103,98,110	260.	53.
521	35,43,61,52,73,94,103,99,110	260.	53.
522	35,43,61,52,73,94,103,99,110	310.	65.
523	36,44,62,51,74,91,93,97,101,110	261.	59.
524	36,44,62,51,74,94,101,99,110	301.	68.
525	36,44,62,51,74,94,102,98,114	424.	92.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
526	31,34,43,61,51,73,91,92,97,103,110	262.	56.
527	31,34,43,61,51,73,91,92,97,103,110	318.	64.
528	37,44,63,52,74,91,93,96,102,114	262.	56.
529	37,44,63,52,74,94,101,98,114	263.	58.
530	37,44,63,52,74,94,103,99,110	312.	69.
531	37,44,63,52,74,94,102,99,110	316.	62.
532	37,44,63,52,74,94,101,99,110	359.	76.
533	30,34,44,63,51,71,91,93,96,103,110	262.	54.
534	37,43,63,51,73,91,92,97,103,110	262.	59.
535	37,43,63,51,73,91,92,97,103,110	272.	58.
536	37,43,63,51,73,91,93,97,103,110	332.	68.
537	30,33,43,61,51,71,91,92,97,103,114	263.	48.
538	30,33,43,61,52,74,94,103,99,114	265.	55.
539	30,33,43,61,52,74,94,103,99,114	358.	66.
540	30,34,43,62,51,74,91,93,97,103,114	266.	55.
541	30,34,43,62,51,74,91,93,97,103,114	308.	64.
542	30,34,43,62,51,74,91,93,96,103,114	344.	63.
543	30,34,43,62,51,74,94,103,98,114	560.	100.
544	37,44,63,51,74,91,93,97,102,114	266.	59.
545	37,44,63,51,74,94,101,99,114	343.	75.
546	37,44,63,51,74,94,103,99,110	449.	96.
547	35,43,61,51,74,91,93,97,103,110	270.	54.
548	35,43,61,51,74,94,103,99,110	306.	63.
549	35,43,61,51,74,91,93,96,103,114	349.	66.
550	35,43,61,51,74,94,103,98,110	374.	79.
551	31,34,44,61,52,74,91,93,96,101,114	271.	57.
552	31,34,44,61,52,74,94,101,99,110	294.	57.
553	31,34,44,62,52,73,94,103,99,110	272.	56.
554	35,43,61,51,71,91,92,96,103,114	272.	53.
555	35,43,61,51,71,94,103,99,114	312.	57.
556	35,43,61,51,71,94,103,98,114	335.	61.
557	31,34,44,63,51,71,91,92,97,102,114	273.	56.
558	31,34,44,63,51,71,91,92,97,103,110	283.	57.
559	31,34,44,63,51,71,94,102,99,114	369.	73.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
560	30,33,44,63,51,71,91,92,96,101,114	273.	55.
561	30,33,44,63,51,71,91,92,96,103,110	279.	55.
562	37,43,61,51,73,91,92,96,103,114	274.	58.
563	37,43,61,51,73,94,103,99,110	363.	82.
564	35,44,62,51,73,91,93,96,102,114	275.	55.
565	35,44,62,51,73,91,93,96,101,110	318.	66.
566	35,44,62,51,73,94,101,99,110	384.	81.
567	35,44,62,51,73,94,102,99,114	461.	93.
568	30,34,43,61,51,72,94,103,98,114	275.	55.
569	30,34,43,61,51,72,94,103,98,110	293.	55.
570	30,33,44,62,52,74,94,102,98,114	275.	57.
571	30,33,44,62,52,74,94,102,99,110	287.	60.
572	30,34,44,61,51,72,91,93,96,101,110	276.	55.
573	30,34,44,61,51,74,91,93,97,103,114	277.	62.
574	30,34,44,61,51,74,91,93,97,103,110	282.	57.
575	37,43,63,51,74,91,93,96,103,110	278.	59.
576	37,43,63,51,74,94,103,98,110	348.	73.
577	37,43,63,51,74,94,103,99,114	382.	84.
578	37,43,63,51,74,94,103,98,114	620.	108.
579	31,34,44,61,52,72,94,102,99,110	280.	55.
580	31,34,44,61,52,72,94,102,99,110	296.	60.
581	31,34,43,63,51,72,91,93,97,103,114	280.	51.
582	31,34,44,61,52,71,94,102,99,114	281.	59.
583	31,33,43,63,52,74,91,93,97,103,110	281.	59.
584	37,44,62,52,72,94,102,99,110	282.	57.
585	31,34,44,63,51,72,91,93,96,102,110	284.	57.
586	31,34,44,63,51,72,94,101,98,110	392.	76.
587	31,33,44,61,51,73,91,93,96,103,114	284.	62.
588	31,34,44,61,51,73,91,92,96,103,110	284.	59.
589	31,34,44,61,51,73,91,93,96,103,114	291.	60.
590	31,34,44,61,51,73,94,102,98,110	412.	83.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
591	36,43,63,51,74,91,93,96,103,114	285.	58.
592	36,43,63,51,74,91,93,96,103,114	303.	64.
593	36,43,63,51,74,91,93,97,103,114	354.	65.
594	36,43,63,51,74,94,103,99,110	385.	90.
595	30,34,44,62,52,72,94,102,99,110	285.	54.
596	31,33,44,62,51,74,91,93,97,103,114	286.	58.
597	31,33,44,62,51,74,94,102,98,114	458.	95.
598	35,43,63,51,72,91,93,96,103,114	288.	58.
599	35,43,63,51,72,94,103,98,114	295.	64.
600	35,43,63,51,72,94,103,98,110	296.	62.
601	35,43,63,51,72,91,93,97,103,114	314.	63.
602	35,43,63,51,72,94,103,99,114	333.	69.
603	35,43,63,51,72,91,93,97,103,114	346.	60.
604	35,43,63,51,74,91,93,97,103,110	289.	60.
605	35,43,63,51,74,91,93,97,103,110	308.	64.
606	35,43,63,51,74,91,93,97,103,114	315.	64.
607	35,43,63,41,74,94,103,99,114	364.	80.
608	35,43,63,51,74,94,103,99,110	381.	83.
609	35,43,63,51,74,94,103,98,110	427.	80.
610	31,33,44,63,51,72,94,102,98,114	289.	61.
611	31,33,44,63,51,72,94,102,99,110	361.	62.
612	31,33,44,63,51,72,94,102,98,110	385.	80.
613	31,34,43,61,51,72,91,93,97,103,110	290.	55.
614	35,43,63,51,73,91,92,97,103,114	290.	61.
615	35,43,63,51,73,94,103,99,110	349.	68.
616	35,43,63,51,73,91,92,96,103,114	358.	73.
617	35,43,63,51,73,94,103,98,114	384.	74.
618	35,43,63,51,73,94,103,99,114	435.	89.
619	35,43,63,51,73,94,103,98,114	444.	85.
620	31,34,44,62,51,71,94,101,98,114	291.	60.
621	31,34,44,62,51,71,94,102,98,110	327.	65.
622	35,44,61,51,73,91,92,97,103,110	292.	59.
623	35,44,61,51,73,94,102,99,114	365.	76.
624	35,44,61,51,73,94,103,99,110	367.	76.
625	36,43,62,51,73,91,92,97,102,110	292.	65.
626	36,43,62,51,73,94,103,99,114	351.	75.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
627	31,33,43,61,52,74,91,93,97,103,110	292.	58.
628	31,34,43,62,51,74,91,93,96,103,114	293.	59.
629	31,34,43,62,51,74,91,93,97,103,114	336.	69.
630	31,34,43,62,51,74,94,103,99,114	398.	79.
631	31,33,44,63,52,73,91,93,97,103,110	294.	61.
632	31,33,44,63,52,73,91,92,96,102,114	331.	67.
633	31,33,44,63,52,73,94,101,99,114	339.	75.
634	31,33,44,63,52,73,91,92,96,103,110	346.	74.
635	31,33,44,63,52,73,91,92,97,101,114	369.	73.
636	31,33,44,63,52,73,94,103,98,114	388.	75.
637	37,43,62,51,73,91,93,97,103,114	295.	59.
638	31,34,44,62,51,73,91,92,97,102,114	296.	64.
639	31,34,44,62,51,73,91,93,96,103,114	323.	65.
640	31,34,44,62,51,73,91,93,97,101,114	346.	71.
641	31,34,44,62,51,73,94,101,98,110	364.	76.
642	30,34,43,63,51,71,91,93,97,103,110	298.	58.
643	30,34,43,63,52,71,91,93,96,103,110	299.	54.
644	30,34,43,63,52,71,94,103,98,110	305.	63.
645	30,34,43,63,52,71,94,103,98,114	395.	74.
646	35,44,63,51,74,91,93,97,102,110	301.	63.
647	35,44,63,51,74,91,93,96,101,110	311.	64.
648	35,44,63,51,74,91,93,96,101,110	318.	71.
649	35,44,63,51,74,94,101,99,114	378.	77.
650	35,44,63,51,74,94,102,98,114	517.	105.
651	31,33,43,62,51,74,94,103,98,110	302.	62.
652	31,33,43,61,52,73,94,103,99,114	302.	57.
653	30,34,43,61,52,74,94,103,98,110	303.	62.
654	37,44,61,51,71,94,103,98,110	304.	62.
655	35,43,62,51,74,91,93,96,103,114	305.	66.
656	35,43,62,51,74,94,103,99,110	343.	74.
657	31,33,43,62,52,73,91,93,96,103,110	305.	61.
658	30,34,43,62,52,73,91,93,96,103,110	307.	58.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
659	31,34,43,62,52,71,94,103,99,114	308.	64.
660	31,34,43,62,52,71,94,103,98,114	316.	61.
661	30,33,44,62,52,73,94,103,98,110	308.	63.
662	30,33,44,63,51,74,91,93,97,102,110	309.	66.
663	30,33,44,63,51,74,91,93,96,103,114	343.	69.
664	30,33,44,63,51,74,94,102,98,110	455.	90.
665	31,34,44,63,51,74,91,93,97,103,114	310.	63.
666	36,44,63,51,72,94,103,99,110	310.	68.
667	36,44,63,51,72,94,103,99,110	311.	69.
668	36,44,63,51,72,94,101,99,110	345.	70.
669	37,44,63,51,73,91,92,97,103,110	312.	62.
670	37,44,63,51,73,94,103,98,110	392.	81.
671	37,44,63,51,73,94,101,99,114	403.	86.
672	37,44,63,51,73,94,101,98,110	448.	89.
673	30,34,43,61,51,73,91,92,97,103,110	312.	64.
674	30,34,43,61,51,73,94, 103,98,110	377.	69.
675	31,33,44,62,51,72,94,103,99,110	312.	63.
676	31,34,43,63,52,71,94,103,99,114	315.	59.
677	31,34,43,63,52,71,94,103,99,114	410.	74.
678	30,34,43,63,52,74,94,103,98,110	315.	67.
679	30,34,43,63,52,74,94,103,98,114	317.	66.
680	30,34,43,63,52,74,94,103,98,110	330.	67.
681	30,34,43,63,52,74,94,103,98,114	363.	73.
682	30,34,43,63,52,74,94,103,99,110	397.	75.
683	30,33,44,62,51,71,94,103,99,114	316.	63.
684	31,34,43,62,51,73,91,93,97,103,110	318.	64.
685	31,34,43,62,41,73,91,93,97,103,110	357.	70.
686	31,34,43,62,51,73,94,103,99,110	389.	80.
687	31,34,43,62,51,73,94,103,98,114	460.	95.
688	30,34,43,63,51,74,91,93,96,103,110	318.	67.
689	30,34,43,63,51,74,94,103,99,110	482.	98.
690	30,34,43,63,51,74,94,103,98,114	506.	99.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
691	30,33,43,51,51,73,91,92,96,103,114	319.	63.
692	30,33,43,61,51,73,91,92,97,102,114	330.	65.
693	30,33,43,61,51,73,91,92,97,103,110	346.	68.
694	30,33,43,61,51,73,94,103,99,110	475.	97.
695	30,33,43,61,51,72,94,103,99,114	319.	69.
696	31,34,44,61,51,74,91,93,96,101,110	319.	68.
697	31,34,43,62,52,73,94,103,99,110	320.	65.
698	31,34,43,62,52,73,91,93,97,103,110	322.	63.
699	36,44,63,51,71,94,103,98,110	320.	69.
700	31,33,43,62,51,72,94,103,99,110	321.	62.
701	31,33,43,62,51,72,94,103,99,114	344.	65.
702	30,34,44,62,51,73,91,93,97,102,110	321.	67.
703	30,33,44,63,51,73,91,92,97,102,110	321.	68.
704	30,33,44,63,51,73,94,103,98,114	384.	80.
705	30,34,43,61,51,74,94,103,99,114	322.	66.
706	30,34,43,61,51,74,94,103,98,110	426.	82.
707	31,33,44,61,51,71,94,101,99,110	324.	68.
708	31,33,44,62,52,73,94,101,98,114	325.	68.
709	31,33,44,63,51,73,91,92,97,101,114	327.	67.
710	31,33,44,63,51,73,94,101,98,110	457.	89.
711	30,33,43,63,51,72,91,93,96,103,114	328.	66.
712	30,33,43,63,51,72,94,103,98,114	415.	75.
713	30,34,44,61,51,71,94,102,98,114	328.	67.
714	30,33,43,62,51,74,91,93,97,103,114	330.	62.
715	35,43,63,51,71,94,103,98,110	331.	72.
716	31,33,43,63,51,74,91,93,97,103,114	331.	66.
717	30,33,43,62,52,73,94,103,99,114	333.	70.
718	31,34,43,63,41,74,91,93,97,103,114	335.	68.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
719	30,33,43,62,51,73,94,103,98,114	336.	66.
720	30,33,43,62,51,73,91,93,96,103,114	351.	67.
721	30,33,44,63,51,72,94,103,98,110	336.	66.
722	35,44,63,51,73,94,101,98,114	338.	73.
723	35,44,63,51,73,94,102,99,114	338.	73.
724	35,44,63,51,73,94,101,99,114	395.	79.
725	30,33,43,61,52,73,94,103,98,110	338.	63.
726	30,33,43,63,52,72,94,103,99,110	340.	70.
727	30,33,43,63,52,72,94,103,98,110	381.	71.
728	30,33,43,61,51,74,91,93,97,103,114	342.	70.
729	31,33,43,63,51,73,91,92,97,103,110	346.	71.
730	31,33,43,63,51,73,91,93,97,103,110	375.	71.
731	31,33,43,63,51,73,91,92,96,103,110	452.	84.
732	30,34,43,62,51,73,94,103,98,114	347.	68.
733	30,33,44,61,51,71,94,101,98,110	348.	68.
734	30,33,44,61,51,71,94,102,99,110	353.	71.
735	30,34,44,63,52,73,94,102,98,114	350.	63.
736	36,44,62,51,73,94,103,98,114	351.	76.
737	36,44,62,51,73,94,103,99,114	352.	72.
738	31,33,43,61,51,74,91,93,96,103,114	353.	70.
739	31,33,43,61,51,74,91,93,96,103,114	424.	85.
740	31,33,43,61,51,74,94,103,98,110	426.	86.
741	31,33,43,61,51,73,91,93,96,103,114	353.	76.
742	31,33,44,63,52,72,94,101,98,110	353.	70.
743	30,34,43,63,52,73,94,103,99,110	355.	72.
744	31,33,44,61,51,72,94,102,98,110	358.	70.
745	30,34,43,62,51,71,91,92,97,103,114	360.	68.
746	31,33,43,63,52,72,94,103,98,114	361.	71.
747	31,33,43,63,52,72,94,103,99,110	380.	76.

TABLE K4. (continued)

Machinery System Number	Network Nodes	Total cost (nearest $) $/T DP Fed	$/T DM Fed
748	31,33,43,61,51,71,91,93,96,103,110	362.	66.
749	30,34,44,61,51,73,94,102,98,114	364.	73.
750	30,34,44,61,51,73,94,101,99,114	424.	80.
751	30,34,44,63,51,74,91,93,96,103,114	367.	72.
752	30,34,44,63,51,74,94,103,99,114	502.	98.
753	31,34,43,63,51,73,91,93,97,103,110	369.	74.
754	30,33,44,61,51,73,94,103,99,114	374.	79.
755	30,34,43,61,52,72,94,103,99,114	379.	71.
756	30,34,44,63,52,74,94,102,99,110	388.	80.
757	30,34,44,63,52,74,94,101,98,110	442.	86.
758	30,33,43,63,51,71,94,103,99,110	391.	80.
759	30,33,43,63,51,71,94,103,98,110	417.	83.
760	30,33,43,63,51,71,94,103,98,110	442.	83.
761	31,34,44,62,51,74,94,103,99,110	391.	80.
762	31,34,44,62,51,74,94,101,98,110	466.	97.
763	30,33,43,63,51,73,91,92,97,103,110	398.	74.
764	30,33,43,63,51,73,94,103,99,114	409.	82.
765	31,33,43,63,51,71,94,103,99,114	399.	77.
766	31,33,43,63,51,71,94,103,99,114	457.	89.
767	30,34,43,63,51,73,91,92,96,103,110	401.	75.
768	30,33,44,62,51,74,91,93,96,101,114	403.	78.
769	30,33,43,63,51,74,91,93,96,103,110	414.	79.
770	30,33,43,63,51,74,91,93,96,103,110	424.	79.
771	30,33,43,63,51,74,94,103,98,110	441.	83.
772	31,34,43,63,52,73,94,103,99,114	431.	87.
773	30,33,44,62,51,73,94,101,99,110	438.	89.
774	30,33,44,62,51,73,94,103,98,114	453.	89.
775	31,34,43,61,51,74,94,103,99,114	537.	107.
776	31,33,44,62,51,73,94,102,99,110	635.	124.

B29995